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RI-Research Program
General

DIVISION OF WATERSHED MANAGEMENT RESEARCH

Semiannual Report

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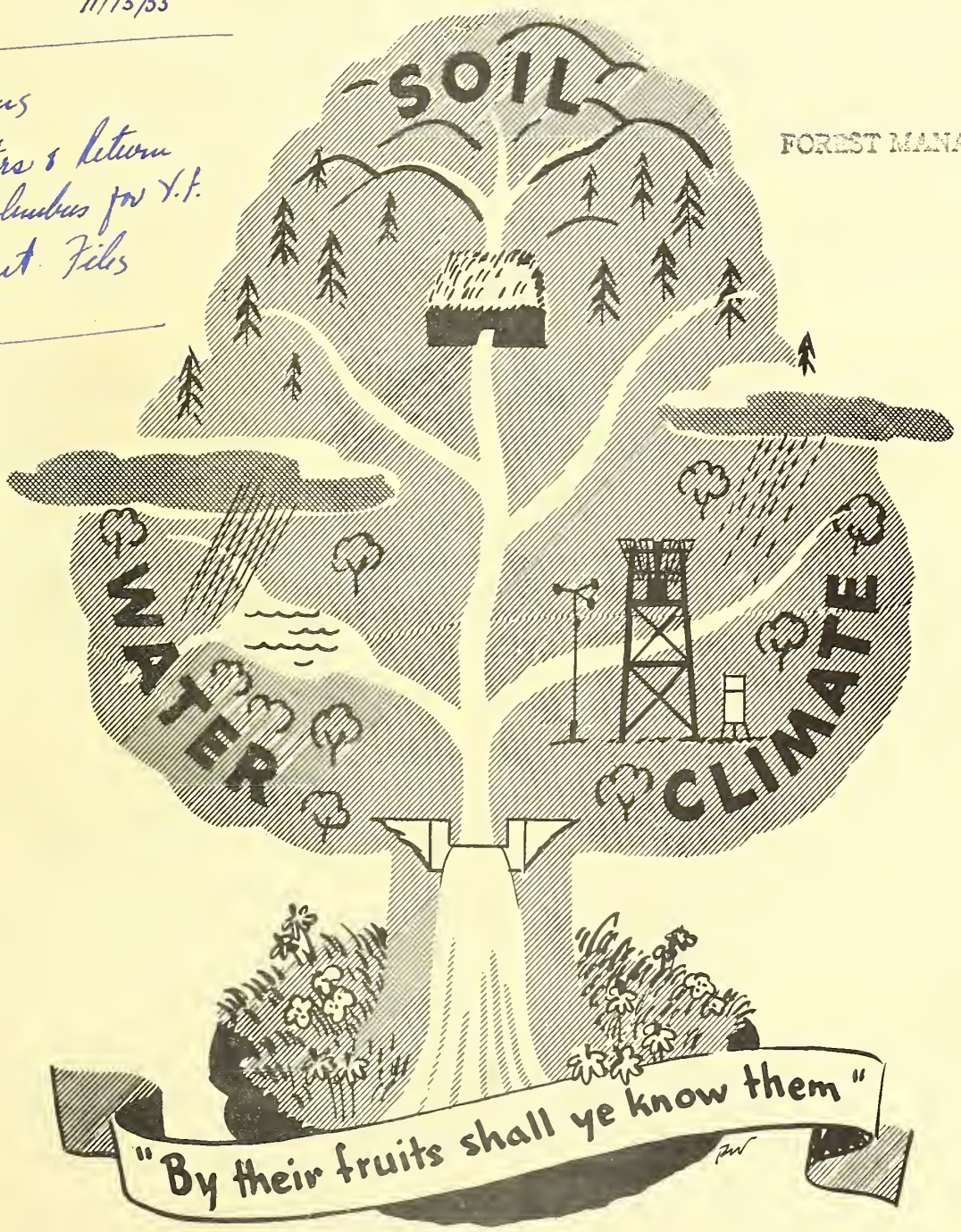

U. S. DEPARTMENT OF AGRICULTURE

FOREST SERVICE

April - September 1955

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SEMIANNUAL REPORT
Division of Watershed Management Research
April - September 1955

Washington Office Activities

Personnel recruitment matters and field consultations, budget statements and technical reviews have occupied much of Herb Storey's time during the past six months. Most of the field divisions' personnel needs created by the increased appropriation for watershed research have now been met and the expanded program appears to be well along.

Under review is a lengthy statement by Hoyt on hydrologic, mapping, resource survey, and other basic data needs in preparation for a book by him and Langbein for the Conservation Foundation. Those aspects of the book dealing with watershed research accomplishments should be strengthened as a result.

Recently assembled is a bibliography on watershed management publications by FS personnel covering the period 1905-1954, inclusive. Copies will soon be distributed. It is suggested that the bibliography be carefully checked for omissions, etc. so that we may incorporate the corrections in the next release.

At Storey's suggestion, Bernie Frank has been asked to prepare a Department bulletin on watershed management research by the Forest Service to acquaint cooperators, our Research Advisory Committee members, and other interested parties within and outside the Forest Service with the nature, scope and accomplishments of our program. The bulletin is planned as a semi-technical publication to increase its understanding and usefulness. A detailed outline has been prepared but actual writing has not yet begun.

Several months ago the SCS prepared a report to ARS on "Soil and Water Conservation Research Needs." ARS together with the FS is preparing a report on consideration given and action taken on the needs listed by SCS. The Divisions of Forest, Range, and Watershed Management Research are preparing material for the FS section of the report. The statements submitted by the Stations on their active and proposed projects in connection with the forthcoming meeting of Division Chiefs following the Watershed Management Conference have proved a highly valuable and timely source of information.

Preparations for the Watershed Management Conference are practically completed. All papers by watershed researchers have been received and approved for mimeographing as tentative drafts. Judging by their tone and quality, we can expect the papers to stimulate constructive thinking and discussion on the subject.

Next meeting of the Department's Advisory Committee on Soils, Water, and Fertilizer Research is scheduled for January 16-19 at Riverside, Cal. A day's visit to the San Dimas Experimental Forest, including a half-day tour of the more accessible experimental installations, is on the program.

(Over)

Soil Management will feature the 1957 Agricultural Yearbook. Dr. Harper, FS Committee member, has drawn on the Division for suggestions on subject matter and orientation. (Dr. Charles E. Kellogg heads the Committee.)

"Hydrograph Analysis by the Method of Least Squares" is the title of an article in ASCE Proceedings, Vol. 81, Paper No. 793, by TVA hydraulic engineer Willard M. Snyder. Using data from the White Hollow watershed in Tennessee--now virtually all forested--and the much smaller Waynesville experimental watershed in North Carolina in pasture--the author develops coefficients of runoff distribution for 5 storms on each area. In the case of the area with stable cover (Waynesville), the coefficients indicate no change in the shape of the total storm hydrograph. On White Hollow, where the cover has appreciably improved, the storm hydrograph has undergone a significant change in shape.

SEMIANNUAL REPORT -- APRIL THROUGH SEPTEMBER 1955

Division of Watershed Management Research

California Forest and Range Experiment Station

GENERAL

Watershed Management Conference

Reports were prepared by Colman and Sinclair for a panel discussion of Research Contributions and Deficiencies at the Forest Service Watershed Management Conference to be held during the week of November 14 at Denver. Colman will discuss "Additional Research Needs." Sinclair's topic is "Relation of Regular Continuing Research to Short-term Administrative or Operational Type Studies."

A. E. Wieslander also will represent the California Station at the conference and will discuss "Soil Surveys - Their Value and Use in Wildland Management."

Emergency Flood Prevention Team

A 7-man Forest Service flood prevention team was recently organized in Region 5 as the result of a recommendation by the Forest Supervisors of southern California. The team is to make flood hazard surveys and plan needed emergency flood prevention measures immediately following fires on the national forests in southern California. The Assistant Regional Engineer is Chief of the team. Other members of the team are from the Regional Office with an alternate designated from Watershed Management Research. Phases of the flood prevention planning job assigned to specialists on the team include emergency structural measures, denuded area reseeding, aircraft use in seeding, hydrology, and soil capability.

The team was called into action for the first time as a result of the 76,000-acre Refugio fire on the Los Padres Forest during September. Rowe served as hydrologist for this action.

Watershed Management Field Trip

Hamilton, Hellmers, Rowe, and Anderson of the San Dimas staff joined Colman, Gleason, and Kraebel of the Berkeley staff in a watershed management inspection tour, June 6-14. Viewed and discussed were the watershed management research implications of a complex of land use and resource developments in the southern Cascade and northern Sierra Nevada Ranges. On the Plumas National Forest, Supervisor Peterson and his staff displayed water and power facilities, salvage logging and reforestation of burned areas, development of access roads in areas of unstable soil and bedrock, and problems of gully development in mountain meadows. At Blacks Mountain Experimental Forest, the application to watershed management of "unit area control," risk cutting, and skid trail location and treatment were

viewed. In and around Harvey Valley results of conversions of sagebrush to grass were seen, together with more gullies in mountain meadows. At Sage Hen Creek trout management studies of the University of California were observed under the guidance of Prof. Paul R. Needham. The trip wound up at the Central Sierra Snow Laboratory where research facilities were inspected.

PERSONNEL

H. W. Anderson transferred from the San Dimas Research Center on September 1 to the new position of Snow Research Leader in the Division of Watershed Management Research at Berkeley.

Robert A. Merriam is being transferred from the Station's Division of Range Research to the Division of Watershed Management. When he reports to the San Dimas Research Center on October 3 he will have achieved the distinction of being the first Junior Forester to be assigned there since Ted Colman's arrival in December 1935.

Henry Hellmers was promoted from "Research Fellow" to "Senior Research Fellow" on the staff of the California Institute of Technology.

PUBLICATIONS

Manuscripts Published

"Development of Vegetation after Fire in the Chamise Chaparral of Southern California" by J. S. Horton and C. J. Kraebel. Ecology 36(2), April 1955. (Described in Semiannual Report, October 1954-March 1955, page 4.)

"Effects of the Forest Floor on Disposition of Rainfall in Pine Stands" by P. B. Rowe. Jour. Forestry 53(5):342-348, May 1955. (Abstracted in Semiannual Report, April-September 1953, pages 4-5.)

"Soil Fertility: A Watershed Management Problem in the San Gabriel Mountains of Southern California" by Henry Hellmers, James F. Bonner, and John M. Kelleher. Soil Science, September 1955. (Described in Semiannual Report, October 1954-March 1955, page 4.)

"Watershed Damage -- Its Signs and Causes" by Clark H. Gleason, Paul E. Packer, and Roy D. Hockensmith. American Forests, June 1955, pages 34-37. Noting that much watershed damage can be avoided if its signs are recognized in time, the article points out some common indicators of damage and describes some land uses and abuses that cause it. Thus a satisfying "30" was written to one of the articles intended for the Yearbook.

Manuscripts Accepted for Publication

"Conquering Kennett's Gullies -- Reforestation of a Smelter-Denuded Area in California" by C. J. Kraebel, has been accepted by

American Forests. (Described in Semiannual Report, October 1954-March 1955, page 5.)

"Root Systems of Some Chaparral Plants in Southern California" by Henry Hellmers, J. S. Horton, G. Juhren, and J. O'Keefe, has been accepted by Ecology. (Described in Semiannual Report, October 1953-March 1954, page 3.)

New Manuscripts

"Uses of Soil-vegetation Survey Information in Watershed Management" by P. B. Rowe and E. A. Colman, has been submitted for publication in the Soil Science Society of America Proceedings. Soil-vegetation information required to manage wildlands for flood and erosion control, and the need for improved methods for measuring the hydrologic properties of soils are discussed in this paper. In addition, the hydrologic properties of three wildland soils in Mendocino County, California are described, and these properties are interpreted in terms of some of their watershed management implications.

"Application of the Earhart Plant Research Laboratory to Field Problems" by Henry Hellmers. This is to be a chapter in a book being edited by Dr. F. W. Went titled "The Experimental Control of Plant Growth" for Chronica Botanica.

CURRENT RESEARCH

SNOW STUDIES

Now available are the basic data on intensity of solar radiation on slopes, used in the study "Forest Cover Effects on Snowpack Accumulation and Melt, Central Sierra Snow Laboratory" by H. W. Anderson, submitted to the American Geophysical Union for publication. The intensity of solar radiation (Sin Θ) at latitude 34° for hour angles by 30° intervals, slopes by 10 percent increment from 0 to 100 percent, and azimuths by 45° intervals for solar declinations by 2° were compiled several years ago under the direction of W. L. Fons of the Fire Research Division. In all, there are about 60 page-size tables of data. Film negatives of these tables have been made, and ozalid-type prints can be made on request. Supplementary data for some slopes at other latitudes appear in the August 1955 and two subsequent issues of "Heating, Piping and Air Conditioning Magazine."

SAN DIMAS EXPERIMENTAL FOREST

State Participation in Watershed Research

Since 1947 research on the San Dimas Experimental Forest has been conducted with financial assistance from the State of California through its Division of Forestry. A report of research accomplishments on the San Dimas Forest during fiscal year 1955 was submitted to the Division of Forestry, together with a statement of plans for fiscal year 1956. The plans call for a broadened program of watershed management research growing out of the review of research on the San Dimas Forest noted in the last semiannual report.

The proposed research program extends studies already underway and adds additional work of high priority. The program has four major parts, as follows:

1. Watershed hydrology.--Studies to determine how brush-covered watersheds function and how soil and water movement are influenced by conditions of rainfall, vegetation, soil, geology, and topography.

2. Management of vegetation on upland slopes.--Studies to determine if, how, and how much water yield can be increased, without increasing storm runoff and erosion, by treating the vegetation on upland slopes having well drained soils.

3. Management of riparian vegetation.--Studies to determine whether and to what extent dry-season streamflow can be increased by manipulation of the riparian vegetation along stream channels without materially reducing stability of the channels or the slopes above them.

4. Treatment of slopes recently burned-over.--Studies to develop and determine the effectiveness of vegetative and other kinds of treatment on fire denuded watershed slopes to reduce surface runoff and erosion.

Continued cooperation by the State is important to the conduct of this research program.

Monroe Canyon Small Watershed Project

Los Angeles County Flood Control District has sponsored an application for a small watershed (Public Law 566) project in Monroe Canyon, a tributary of Big Dalton drainage within the San Dimas Experimental Forest. Channel structures and possibly other measures are proposed that would become integral parts of our hydrologic studies in this 875-acre watershed.

The Monroe Canyon application has been approved by the State Soil Conservation Commission. The work plan for the project is to be prepared by the Forest Service in cooperation with the Flood Control District.

Streamflow Calibration

Calibration analyses of weekly mean streamflow from watersheds VIII, IX and X in the Big Dalton drainage (as described in the October 1954-March 1955 and preceding semiannual reports) was continued. Multiple regression analyses (1) using a combination of meteorological controls and streamflow from Watershed IX, and (2) using meteorological controls alone have been completed for the wetting and percolation periods. Similar analyses for the drying period are nearing completion. An office report describing the methods employed and results obtained from the streamflow analyses of the three watersheds will be prepared.

Rainfall Disposition Study - Tanbark Plots

How percolation and seasonal water use were affected by changing brush cover to grass is suggested by preliminary analyses of the first three years of data from plots at Tanbark Flat. The plots studied were originally covered with scrub oak and other native brush. In 1951 one set of plots was converted to ryegrass cover, and the other was left undisturbed. Soil of the grass plots is 14 feet deep, and that of the brush plots 17 feet. Data from three hydrologic years were analyzed: 1951-52 with 41 inches of rainfall, 1952-53 with 15 inches, and 1953-54 with 25 inches. The analyses indicate that the degree to which evaporative losses are altered by the change in vegetation will depend on depth of soil and the amount of rain in a year.

On the plots converted from brush to grass the soil during each rainy season was wetted to field capacity throughout its depth of 14 feet. Each succeeding summer the soil dried or was dry below field capacity to a depth of 7 feet, and below wilting point to a depth of 3.3 feet.

On the undisturbed brush plots the soil was wet to field capacity throughout its 17-foot depth the first winter. But during the next two winters, of 15 and 25 inches rainfall, the soil was wet to field capacity to depths of only 4 and 10 feet respectively. During each summer the brush-plots soil dried below field capacity to a depth of 12 feet, and to or below wilting point to a depth of 9.6 feet. Thus there was a greater carry-over of moisture each summer in the 4- to 12-foot depth of soil under grass than under brush.

During 1952-53 the 15 inches of rain were insufficient to produce percolation from the base of the soil mantle of either the grass or brush plots, and evapotranspiration from both was nearly the same. But during 1953-54, with 25 inches of rain, more water percolated and less was lost by evapotranspiration under grass than under brush.

The results indicate that in this area evapotranspiration from brush- or grass-covered soils less than 4 feet deep would be about the same, and that little or no water would be saved by converting brush to ryegrass cover. For soils deeper than 4 feet, conversion of brush to ryegrass would result in a saving of water in years of rainfall sufficient to wet the soil below this depth. The chances of improving water yield in the San Gabriel Mountains by changing brush to grass cover are limited, however, because only about 10 percent of the area has soils greater than 4 feet deep. Moreover, the deeper soils occur, for the most part, in small, scattered areas.

Instrumentation

Collection of field data from streamgaging stations on the San Dimas Forest for the calibration of 90° V-notch weirs for low flows was completed during July. Measured volumes of flow were made at several low stages (H less than 0.2 feet). These calibration data were needed to improve the present rating table for low stages and thus permit more accurate computations of streamflow, particularly for the Bell and Fern small watersheds.

Andrews has devised a reversal indicator for the Friez FW-1 water stage recorder. The device employs a pen bearing along the bottom margin of the chart. This pen changes position when the recorder pen reaches either top or bottom of the chart. The device has been recommended to Bendix-Friez for incorporation in their instrument.

Hamilton has worked out a circuit breaker which, incorporated in an anemometer and wind direction transmitter circuit, will make only an instantaneous contact. This should prove useful in conserving battery energy where instruments are located in remote regions.

LOS ANGELES RIVER WATERSHED

The work formerly done under the designation of "Cover Improvement" has been given a more descriptive title, "Stabilization, Critical Sediment Sources," as recommended by D. M. Ilch. This subject is divided into two parts: the Soil Movement Study, and the Vegetation Study.

An operation plan for this work during fiscal year 1956 was drawn up by the San Dimas staff. The plan was reviewed at a meeting in June 1955 by representatives of Region 5, Angeles National Forest, and the California Station. It was agreed that the work should be concentrated on four items: (1) continuation of measurement of the rates and processes of soil movement from the slopes at nine existing installations, (2) establishment of new installations for measuring soil movement in critical frontal areas of the San Gabriel geologic type, (3) continuation of the selection of desirable plants for slope stabilization on critically eroding slopes, and (4) continuation of field trials of methods of plant establishment and slope stabilization on critical eroding areas. It was proposed also to include mechanical methods of slope stabilization with the present evaluations of vegetative methods.

As a result of these discussions the Station is planning to continue slope stabilization work in the Los Angeles River Watershed as outlined above, in cooperation with Region 5, the Angeles Forest, and the California Institute of Technology.

Soil Movement Study

Field measurements were extended in November 1954 by the establishment of four new study sites equipped with catchment troughs. The new sites are in the south fork of Brown Canyon in the Arroyo Seco drainage, near the old "Lower Brown" study site. Two of the new sites are on south-facing slopes and two on north-facing slopes. The new sites furnish additional replications of areas shown to be principal sources of sediment production. They also extend the range of slope lengths from which soil movement is being measured, to a maximum of 450 feet, about double the length of the old sites. The new study sites can be broken into six "natural slope strips" thus supplying additional areas for either tests or controls. Soil movement catches from these sites for the wet season in 1955 are given in Table 1.

Table 1.--Soil caught below slopes at soil movement study sites

Season	Study Site: Lower Brown #1 (north rejuv.)	Lower Brown #2 (north rejuv.)	Lower Brown #4 (south rejuv.)	Lower Brown #5 (south rejuv.)
	Tons per acre			
Wet season Dec. 1, 1954-May 3, 1955	1/ 0.12	1/ 0.10	1.45	0.96

1/ Tentative; areas of sites not yet finally checked.

Catches of soil from the five original soil movement study sites for the second year of study are summarized by seasons in Table 2.

Table 2.--Soil caught below slopes at soil movement study sites

Season	Study Site: Lower Brown #3 (south rejuv.2/)	Upper Brown (south nonrejuv.)	Falls (north rejuv.)	Singing Springs #1 (south nonrejuv.)	Singing Springs #2 (north nonrejuv.)
	Tons per acre				
Drying season June 2-Aug. 31, 1954	0.15	0.15	0.07	0.04	0.05
Dry season Sept. 1-Nov. 1, 1954	0.35	0.06	0.32	0.01	0.03
Wetting season Nov. 1-Nov. 30, 1954	0.22	0.06	0.04	0.01	0.01
Wet season Dec. 1, 1954-May 3,1955	2.77	0.44	0.25	0.15	0.05
Total June 2,1954-May 3,1955	3.49	0.71	0.68	0.21	0.14
Relative rate of delivery	25	5	5	1.5	1.0
Percent organic	6.4	38.3	23.1	14.3	25.5
Direct leaf-fall	0.007	0.019	0.031	0.0006	0.0018

1/ Slope aspect.
2/ Rejuvenated slope.

Comparison of first- and second-year soil catches at the five original sites shows total yearly catches ranging from 0.14 to 5.01 tons per acre the first year, as against 0.14 to 3.49 the second year.

For the south rejuvenated site the catch was only 0.7 as great the second year as in the first year; for the other sites the catch ranged from 1.0 to 1.6 times as great in the second year. Again the south rejuvenated sites were the principal source of sediment.

Catches of soil during the second year varied between sites with seasons. Wet season movement was about 35 percent of the year's movement on the two north-facing sites and ranged from 60 to 80 percent of the year's total on the south-facing sites.

The percent of organic matter in the catches was highly variable from site to site, with a low of 6.4 for Lower Brown (No. 3) and a high of 38.3 for Upper Brown. Part of this organic matter was due to direct leaf-fall into the troughs. Nearly 20 percent of the organic matter caught at the Falls Site was direct leaf-fall. At the other sites direct leaf-fall was 2 to 7 percent of the organic matter.

Soil Moisture Sampling Results

The soil moisture regime of the surface soil has been studied as a means of explaining movement of soil and of guiding treatments for reduction of soil movement. Sampling started early in March 1954 and has been continued to date. At first the sampling was at approximately weekly intervals, but since January 1955 sampling has been at about monthly intervals. Samples were taken under bare soil, under 3/4 inch of litter and under 2 inches of litter, all under a high tree canopy of oaks and California laurel at the Lower Brown (No. 3) study site. The sampling showed these things about the soil moisture regime of the surface 3 inches of soil under high tree canopy.

1. Bare soil dried very quickly, drying from field capacity to wilting point in 3 to 4 weeks in early spring and early winter (March 23 to April 20, 1954, and December 6-28, 1954). In both 1954 and 1955 moisture in bare soil reached the wilting point in April.

2. Soil under 3/4 inch of litter after once being wetted to field capacity in the fall never fell to the wilting point until midsummer--July 16 in 1954 and July 5 in 1955.

3. Soil under 2 inches of litter, after once being wetted to field capacity, never fell to the wilting point until July 21 in both 1954 and 1955.

4. Soil under both litter depths and bare soil dried to 2 percent moisture in the late fall.

5. Following light rains in fall and spring, the bare soil and soil under 3/4 inch of litter often had more moisture than the soil under 2 inches of litter.

6. Soil moisture far in excess of field capacity was noted in soil under litter of both depths 4 to 7 days after rainfalls greater than about 1 inch.

7. Moist pockets of soil under 2 inches of litter occurred as late as June when the bare soil was at the wilting point.

Vegetation Study

Field Tests

In the search for plants suited to soil stabilization use Baccharis pilularis ssp. typica continues to show promise over 22 exotic species tested in the laboratory. The Baccharis grows rapidly, is prostrate, is evergreen, and roots easily. It has grown well under the wide range of temperatures possible in the San Gabriel Mountains and has withstood winter frosts during the past year. It survived summer drought on sites of shallow soil where soil moisture dropped below the wilting point. When transplanted as 6-month-old stock it made 30-60 percent survival where transplants of other exotic species as well as native plants failed.

Spartium junceum, one of the two legumes that appeared most promising as nitrogen fixing plants, withstood frost and drought well. However, it showed a survival rate of less than 25 percent on poor sites. Calycotome villosa, the other nitrogen-fixing legume, was killed by frost.

Laboratory Tests

Tests of the germination and growth of exotic species recommended for soil stabilization have been resumed under controlled conditions in the Earhart Laboratory at the California Institute of Technology. Seeds of about 30 species are on hand for study.

MEETINGS

April 18.--Gleason spoke to Prof. Kartchner's class in Conservation, at San Jose State College, on the subject "Watershed Management and Indicators of Erosion."

April 25-27.--Anderson, Hamilton, Hellmers, and Rowe of the San Dimas staff, together with Colman, Kraebel and Gleason, took part in the Station's Annual Investigative Meeting at Berkeley.

April 27-30.--Colman and Hellmers attended the International Arid Land Conference meetings in Albuquerque, New Mexico.

May 13.--Sinclair attended a meeting of the State Water Resources Board of California held at Los Angeles. Problems concerning the review and approval for publication of the State's Bulletin 2 on water use and estimated future requirements in California were the subject of considerable discussion. The Board approved a survey

of present land use and estimated water requirements in Los Angeles County proposed as a cooperative project by the State Division of Water Resources, Los Angeles County Flood Control District, Metropolitan Water District, and other local interests. The results of the survey are intended to supplement and bring up to date the information for this area contained in the forthcoming Bulletin 2, and particularly to help guide the development of water facilities in this very rapidly growing area. Annual water requirements in Los Angeles County were estimated to be 1,000,000 acre feet in 1950. Since that time there has been an increase of more than 1,000,000 in population, and more than 300,000 new houses have been built. The survey is to be completed in 2 years at a cost of $20,000.

June 20-24.--Hamilton and Hellmers attended some of the meetings of the American Association for the Advancement of Science, Pacific Division, held at California Institute of Technology. Hellmers was co-chairman of the program committee for the section sponsored by the Ecological Society of America.

June 29.--Gleason addressed Prof. Judd's classes in General Conservation and Trees of California, at San Jose State College, speaking on "Watershed Management and Indicators of Erosion."

August 17 and 18.--Colman and Rowe attended the annual meeting of the Soil Science Society of America held at Davis, California, where Colman presented the paper, "Uses of Soil-vegetation Survey Information in Watershed Management," by P. B. Rowe and E. A. Colman.

September 12-14.--Gleason attended the 10th annual meeting of the Soil Conservation Society of America at Green Lake, Wisconsin, and took part in a panel discussion on "Chapter Program Needs Regarding Land Use Problems."

September 28.--At the request of Supervisor Jones of the Los Padres National Forest, Rowe attended a meeting at Santa Barbara held under the auspices of the Carpenteria Farm Center to discuss a program of watershed management and fire prevention along the highly developed ocean front area of Santa Barbara County. Groups represented at the meeting included the California Division of Forestry, County Board of Supervisors, Santa Barbara City Council, Santa Barbara Chamber of Commerce, Montecito Fire Commission, Watershed Fire Council of Southern California, Carpenteria Farm Center, and the Forest Service.

COOPERATION

Plumas National Forest and Regional Office.--At the request of the Regional Forester, Kraebel joined a team of Plumas Forest and Regional Office men in an examination of a proposed project of soil and water conservation in the Last Chance Creek area on the Plumas Forest. Subsequently he reviewed the plan of work and submitted comments and suggestions thereon. The project embraces a watershed of about 50 square miles of mountain and meadow land in which considerable gully control work was done in 1934. The planned rehabilitation includes repair of old and construction of new check-dams and head

plugs in gullies, gully-bank sloping, eradication of sagebrush, grass seeding, and tree planting. The meadows have been fenced and fitted into a rotation grazing program which will benefit both the seeding and structural work.

Vista Irrigation District, San Diego County, California.--On July 11 and 12 a group from San Diego County visited the San Dimas Experimental Forest to inspect and discuss results of our hydrologic research and its application to watershed management problems in southern California. This group included Walter J. Puhn, Forest Supervisor and 2 members of the Cleveland National Forest staff; Linden R. Burzell, Manager-Engineer, and 6 members of the Board of Directors of the Vista Irrigation District; and 4 members of the Citizens Forestry Study Group of San Diego County.

At the request of Mr. Burzell, the above group, including Sinclair and Rowe, spent August 23 on a field inspection and discussion of watershed management possibilities in the Lake Henshaw drainage area. Owing to extreme water shortages, the Directors of the Vista Irrigation District (second largest distributor of water in the Cleveland National Forest area) are exploring ways of increasing the yield of water into Lake Henshaw. Toward this end the following kinds of watershed management treatments were considered:

1. Controlled burning of watershed brush and tree cover to reduce evaporative losses and increase storm streamflow.

2. Reduction of riparian growth to reduce evaporative losses from stream channels and valley lands supporting this type of growth.

3. Development of browse-ways to reduce interception and transpiration losses from upland slopes.

4. Stream channel improvement to reduce detention storage and evaporative losses along the lower reaches of streams.

5. Drainage of valley water basins to reduce retention storage and attendant evaporative losses from areas with water tables perched above the Lake Henshaw water level.

The meeting ended with the decision that inventories of the hydrologic characteristics of the area are needed before watershed treatments to improve water yield are undertaken, particularly in upstream reaches of the drainage. The District plans to investigate the possibilities of obtaining such inventories, including surveys of soil-geology and vegetation.

Los Angeles County Flood Control District.--At the request of the District the San Dimas staff will cooperate in a study of debris reduction by means of channel barriers in mountain watersheds in the

Los Angeles basin. Increased costs and other problems involved in removing sediment deposits from debris basins in the densely populated areas of Los Angeles County have prompted this study. The Flood Control District has set up a Debris Reduction Study Group under the direction of Paul Baumann, Assistant Chief Engineer. R. W. Ferrell, head of the group, has conferred with members of the San Dimas staff regarding plans for the work. The studies proposed include inventories of watershed conditions affecting sediment production, such as geology, soils, vegetation, and topographic features, as well as plans for channel barriers to reduce sedimentation. The treatment of slopes other than by the effect of channel stabilization is not contemplated in the District's preliminary plans.

Division of Forest Fire Research.--Hamilton has been assisting the Station's Division of Forest Fire Research in development of an improved wind recording instrument for a fire-climate survey in California. The problem involves the recording of wind speed and direction at geographically remote locations of difficult accessibility in such a manner that the data can be transcribed directly to punch cards without the necessity of transcribing recorded data manually. Each instrument should include sensing elements for speed and direction and an 8-day recording unit, and should operate on battery power. Hamilton visited many instrument companies in the Los Angeles County and learned much about new recording methods. A device was proposed for recording wind data on magnetic tape in digital code. The data can be decoded and processed electronically to appear in typewritten, carded or graphic form. Instrumentation of this kind can be useful in watershed management and other research. Existing instruments doubtless could be redesigned to operate so that the recorded data can be processed more quickly and accurately than at present.

International Union of Geodesy and Geophysics.--Hamilton was invited to attend a meeting of the Joint Committee on Precipitation held at Zurich, Switzerland on July 25 and 26. He prepared a report to be presented in absentia, presenting published work on precipitation and a resume of a study currently being prepared for publication. The study deals with the error in determining rainfall rates from vertical recording gages located on steep mountain terrain. This Joint Committee represents the International Associations of Hydrology and Meteorology. Members of the Committee are L. Serra (France), President; T. Bergeron (Sweden); A. Fantoli (Italy); E. L. Hamilton (U.S.A.); A. Jakhelln (Norway); P. Kasser (Switzerland); M. A. Kohler (U.S.A.); J. Lugeon (Switzerland); and L. Poncelet (Belgium).

Vicksburg Infiltration Project.--Additional rainfall records from Tanbark Flat were sent to Horton to supplement the soil moisture and other lysimeter and plot data previously supplied to the Infiltration Project.

Columbia University, Department of Geology.--James C. Maxwell, graduate student in geomorphology, has completed a study of eroded land forms in certain watersheds on the San Dimas Forest. The study was started last summer under the direction of Prof. Arthur N. Strahler. James R. Trew, graduate student in geology from Brown University is aiding in this work by carrying on a "check" study in the Bell small watersheds.

Angeles National Forest.--Hellmers with Ranger Wilson and Gus Juhren inspected the Switzer burn in Arroyo Seco Canyon and recommended a sowing mixture of annual ryegrass and black mustard for the less steep, open areas including firebreaks. Juhren plans to supplement the firebreak sowing with transplants of Cistus sp. and Baccharis pilularis ssp. typica. Similar inspections with Ranger Lewis were made of the Oak and West Fork burns in San Gabriel Canyon. A ryegrass and black mustard mixture was again recommended for sowing.

VISITORS

Visitors have come to the San Dimas Experimental Forest from far and wide including French Morocco, Tunis, Australia, Philippines, Union of South Africa, Spain, Formosa, Iraq and Pakistan. The total of 75 visitors in this 6-month period comprised 11 from foreign countries, 45 from schools, colleges and unversities, and 19 foresters, engineers, and others. Visitors at the Berkeley office included one each from Israel, French Morocco, Japan, and Pakistan.

SEMIANNUAL REPORT ON FOREST WATERSHED MANAGEMENT

Central States Forest Experiment Station

Athens Research Center

April - September 1955

General

The summer field season has been chiefly devoted to the establishment of soil-site plots for a current study of the relation between the site quality of upland hardwoods and associated conditions of soil and topography. Laboratory analysis of soil samples taken on these site plots is also continuing.

Routine measurements of soil moisture and water runoff from undisturbed and clearcut hardwood plots at the Vinton Furnace Experimental Forest are continuing.

Rainfall for the spring of 1955 was close to normal, however, summer rainfall fell below average resulting in a late summer drought for this area. August and September were particularly dry months and measurements taken at the experimental forest shows that soil moisture has now been reduced to a level close to the permanent wilting percentage.

Meetings

In April, Boyce and Carmean presented an informal paper at the annual meeting of the Ohio Academy of Science on the preliminary results of studies relating the site quality of black oak to understory plant indicators. Dr. Boyce, ecologist at Ohio University, has been employed as a summer field assistant.

In June, Boyce and Carmean attended the Ohio Forestry Association Forestry Training Camp as instructors in watershed management. This camp is held annually for the purpose of introducing the rudiments of forestry and conservation to selected youths of Ohio.

The staff at the Athens Center constructed an experimental forest watershed model for the annual meeting of the Ohio Forestry Association, Inc., in Columbus. The model was later displayed in the office of the experiment station in Columbus and at Ohio University in Athens. This fall it was displayed at the Ohio State Fair in Columbus. Unauthorized parties removed the model from the fair grounds and it has not yet been recovered.

Publications and Manuscripts

"Some forest and water relations" by Robert W. Merz, Assoc. South. Agri. Workers Proc., 52nd Annual Convention, 1955, p.197.

"Structure of forest soils" by W. H. Carmean, has been submitted to the Ohio Journal of Science.

"Water infiltration is related to physical soil conditions and land use in southeastern Ohio" by W. H. Carmean, is undergoing review and is planned for publication as a station technical paper.

"Site curves for second-growth Douglas-fir on the major soil groups of southwestern Washington" by W. H. Carmean, is undergoing final review and will soon be submitted to Forest Science.

Current Studies

Details concerning current soil-site studies for upland hardwoods have been described in previous semi-annual reports. By the end of 1956 sufficient plots should be established for an analysis of both soil-site and plant indicator-site relationships for black oak. Data are also being taken for other oak species that are associated with black oak and it is expected that the site relations for these species may be analyzed sometime in 1957 or 1958.

Soil moisture studies of clearcut and undisturbed forest land have been continued throughout the summer with the expectation that these measurements will be terminated in November or December when soil moisture levels return to field capacity. A report on this study is planned in 1956.

Surface water runoff measurements from undisturbed forest, clearcut forest, and abandoned fields are continuing. As reported previously old fields have produced much more runoff than have the other two land conditions. The runoff continues to be greater from the lands that were clearcut of oak-hickory forests than from lands in undisturbed forests.

Walter infiltration is related to physical soil conditions and land use in southeastern Ohio. A summary of the results of this study that is soon to be published is as follows:

(1) Water infiltration rates were usually more rapid in soils of even-aged oak forests than in soils of young pine plantations, abandoned old fields, or actively grazed pastures. Slowest infiltration rates were associated with the soils found in upland pastures presently being grazed.

(2) Water infiltration rates were related to bulk density, clay content, and organic matter content of the surface soil, thus indicating that rapid water infiltration rates occur with loose, coarse textured soils that contain a relatively large amount of soil organic matter. It was also found that bulk density, clay content and soil organic matter content were interrelated. Low bulk densities occurred with an increase in organic matter and with a decrease in clay content. A decrease in organic content with increased amounts of clay was also indicated.

(3) Considerable variation occurred among individual observations of soil water infiltration indicating that the soil conditions affecting water infiltration rates are variable, even on small areas of apparently homogeneous soil conditions.

Future Studies

Infiltration studies will be continued on the major land use classes of southeastern Ohio. When sufficient plots are available, regression methods will be used to express the relationship between infiltration and physical soil factors.

The Ohio Division of Water has recently become interested in the watershed management work at the experimental forest. The Division of Water is now exploring the possibility of establishing shallow water table recording wells at the forest in connection with the current study of converting poor site hardwoods to pine by clearcutting. When suitable stream measuring devices are installed, they have indicated interest in studying underground water tables on some of our small watersheds by installing both deep and shallow wells in the study areas.

SEMIANNUAL REPORT OF WATERSHED MANAGEMENT RESEARCH
Intermountain Forest and Range Experiment Station
April-October 1955

Boise Research Center

Logging Disturbance-Sediment Production Study.- All of the installations for studying the effects of ponderosa pine logging disturbance on sediment production from 20 small watersheds in the Boise Basin Experimental Forest were completed last fall. Cutting and logging on replicate sets of 8 compartments was accomplished in 1953 and 1954, as was virtually all of the postlogging erosion control treatment of skid trails and haul roads. Initial measurements were obtained last year on the first 8 compartments logged in 1953 and this year on the second replicate set logged in 1954. Data were obtained on the area of forest floor disturbed by logging, the amount of sediment trapped in debris basins at the mouth of each watershed, and the amount of sediment that has been temporarily trapped between the eroding sources and the debris basins.

The areal extent of logging disturbance ranged from 3.6 to 9.1 percent per compartment. Haul roads constituted 58 percent of the disturbed area, skid trails 29 percent, and landings 13 percent. The amount of eroded sediment was too small to be measured on two of the logged watersheds but ranged from 3 to 171 tons per square mile on the other logged areas. The greatest sediment production came from watersheds in which the haul roads paralleled the drainage bottom.

NFA Sale Area Erosion Control Study.- This season the first measurements and observations were made on four erosion control study areas within the Boise and Payette National Forests. Part of the study is to evaluate the effect of gradient, spacing of cross ditches, and grass seeding on sediment production from haul roads. The other part of the study is to test the effectiveness of different types and spacings of erosion control measures on skid trails.

One set of measurements and observations was obtained on all four study areas following the disappearance of snow. Subsequently, three of the study areas were subject to high intensity summer rains. Such hard rains occur only once in about 4 or 5 years in that locality. Their timely occurrence has thus made it possible in the first year of study to observe the effectiveness of the various control measures under the force of both snowmelt and torrential rain. The large mass of information obtained is now being analyzed.

Logging Road Reseeding Study.- A comprehensive reseeding study was installed on 2.8 miles of logging road within the Little Owl Creek Sale Area on the Boise N.F. this fall. Attempts to establish a soil stabilizing ground cover on the granitic soils in the ponderosa pine type have met with little success to date. This new effort will involve the testing of nine promising grasses, four methods of planting, and site treatment by fertilizer and mulch. The tests will be replicated on north and south exposures.

Great Basin Research Center

Pleasant Creek Evaluation Study.- This summer the Station assumed responsibility for giving technical guidance to a study of the hydrologic and productivity effects of an upstream improvement program in the Pleasant Creek watershed in Central Utah. This is one of the first of the areas to be treated under the provisions of the Small Watershed Demonstration Project Item of the Agricultural Appropriations Act of F.Y. 1954.

A number of circumstances made it necessary to limit the evaluation to a plot study of the infiltration, storm runoff, erosion, and range productivity characteristics of some of the more obvious flood source areas immediately prior to and within three years after their treatment. Most of the study sites were located on high elevation herbaceous range areas. Others were located in aspen, mountain brush, and pinyon-sage areas. The treatments applied to the herbaceous range areas included contour trenching, reseeding, and protection from grazing. Grazing control was the only treatment applied on the other areas.

This summer, infiltrometer tests and records of forage production were made on all sites prior to treatment. Repeat measurements on the permanently staked plots are scheduled for 1958.

Analysis of the first years data is just getting under way. However, the data show very obvious inverse relationships of ground cover to infiltration, runoff, and erosion. Little change is expected to occur in three years on some of the low elevation range areas which were not reseeded or trenched but some substantial changes in forage production and hydrologic characteristics are anticipated in the intensively treated subalpine zone.

A supplementary study was also installed in the subalpine zone this summer to evaluate the effectiveness of contour trenching on the control of runoff and erosion from distinctly gullied areas. To accomplish this, long runoff plots were established in pairs on several treated and untreated, gullied areas.

The effectiveness of the upstream improvement work accomplished to date in the Pleasant Creek watershed was clearly demonstrated this summer during a torrential rain that occurred after the headwaters had been subjected to considerable antecedent rain. This storm produced a mud-rock flood in Pleasant Creek as well as in the drainage to the north. Inspection of channels and slopes revealed that virtually all of the flood waters in Pleasant Creek originated on untreated flood source areas in the subalpine zone. On the treated areas, water filled the contour trenches almost to capacity but there was very little evidence of storm runoff to the channels. Completion of the upstream control work should further drastically reduce the summer flood hazard in Pleasant Creek--but there still remains the problem of determining how much grazing can be tolerated on the watershed without creating a new flood threat.

Manti Canyon Evaluation Study.- With help from the Boise and Wasatch Research Centers, a start was made this summer in evaluating the hydrologic and productivity effects of an extensive reseeding program in the head of Manti Canyon on the Manti-LaSal N.F. The study area was plowed and seeded to grass in 1952. Prior to treatment, paired 1/2-acre plots were located on a variety of slopes, aspects, soils, and plant cover types. One plot in each pair was not treated. The entire area has been protected from livestock grazing since 1952.

This summer infiltrometer tests and plant cover observations were made on the treated and untreated plots. As in the data obtained from the Pleasant Creek study, an inverse relationship of plant cover to runoff and soil erosion is evident. There also appear to be some differences due to variations in soil characteristics and the effects of tillage. Laboratory analyses of soil samples are now under way, the results of which are expected to make it possible to isolate the effects of a number of variables.

The reseeded study area was opened to cattle grazing this fall. Additional infiltrometer tests are planned for the future to determine the effects of grazing on the hydrology, stability, and productivity of the several sites.

Vegetation on Watershed B.- A reinventory of the plant cover on Area B of the paired A and B watersheds at the Great Basin Station was made last summer. Purpose of the reinventory was to determine the effects of the plowing, trenching, and reseeding treatment that was given the area in 1952 with a view toward restoring it from a seriously depleted and eroding condition.

As compared to conditions in 1951, plant cover density on Area B is now more than 50 percent greater and the area is now producing about three times more forage. As shown below, there has been a substantial increase in perennial grasses, a decrease in weedy forbs, with little change in litter.

Inventory years	1951	1955
Plant cover density (percent)	20	33
Live vegetation	14	28
Litter	6	5
Range forage (pounds/acre)	1,110	3,000
Grasses	280	2,600
Forbs	820	400

The new grasses on Area B are both well dispersed and in healthy condition. A further increase in the density of both the grass stand and the litter cover is expected in the next year or two, at which time the area will be used for grazing tests.

WASATCH RESEARCH CENTER

Parrish-Centerville Runoff Relations.- The behavior of streamflow in the Parrish and Centerville basins of the Davis County Experimental Watershed during the period 1936 to date is providing much needed information about the effects of upstream watershed improvement measures on water yields as well as on the control of torrential summer floods. The mixed tree, brush, and herbaceous vegetation on the Centerville watershed has never been seriously depleted, nor has the area produced any summer storm mud-rock floods since settlement. Serious depletion of the plant cover by overgrazing on headwater areas in Parrish Creek brought on devastating summer floods in 1930. This watershed was closed to grazing and the flood source areas were contour trenched and seeded to perennial grasses in 1934.

This treatment program has prevented the recurrence of summer rain mud-rock floods in Parrish Creek. Nearby, impaired watersheds not so treated have continued to produce floods under the impact of rains of less intensity than have been recorded in the Parrish and Centerville watersheds.

Parrish Creek is now producing high quality water. Instead of discharging 100-ton boulders as in the early 30's, streamflow from Parrish Creek now runs as clear as Centerville Creek. The water from both streams is diverted directly into both domestic and irrigation systems.

Restoration of the plant cover on the flood source areas in Parrish Creek has resulted in a slight decrease in the annual yield of water. However, this decrease has occurred only during the months of March, April, and May, when water supplies are generally abundant. There has been no discernable change in yields during the summer and fall months when water is in highest demand.

Further analysis of the Parrish and Centerville streamflow records show the following additional changes:

1. There has been a downward trend in the magnitude of the snowmelt peak charges on Parrish Creek. Though Parrish continues to produce greater snowmelt peak discharges than Centerville, the magnitude of the difference between the discharges of the two streams has been reduced about 50 percent.

2. The date of maximum daily runoff from Parrish Creek is now tending to occur later in the spring. Whereas it tended to occur some 3 days earlier than on Centerville Creek it is now tending to occur 3 days later.

The runoff behavior of Parrish Creek has probably not been fully restored to normal. There is room for further improvement in the plant cover on the flood source areas. More time will also be required for the re-filling of the ripped channels. As those conditions mend, there may be some additional decrease in annual runoff. However, there should also be greater control of storm runoff, decreasingly less sediment production, a further lowering of snowmelt peaks, and a further delay in their occurrence.

Water Spreading-Infiltration Rates.- In the previous issue under "who has the rainiest rain forest" we reported infiltration rates as high as 38 inches per day on a water-spreading project adjacent to the Davis County Experimental Watershed. We have since learned that the Bureau of Reclamation was able to sink water in a 3-acre gravel pit near the mouth of Weber Canyon, north of Farmington, Utah, at an average rate of 186 inches per day per unit of area. The total volume involved was 1,861 acre feet. The water level in a well 217 feet deep about 1/4 mile from the spreading pit rose 34 feet.

Halfway Watershed.- Halfway watershed, a tributary of Farmington Creek in the Davis County Experimental Watershed, was subjected to a high intensity summer rain on July 24 which failed to produce a mud-rock flood. This rain reached a maximum intensity of 4.56 inches per hour during a 5-minute period with a total fall of 0.83 inch. On August 10, 1947, a rain of 0.79 inch total, with a maximum 5-minute rate of 4.92 inches per hour, produced a mud-rock flood. Natural recovery of the vegetation on the flood source areas during the past 8 years, appears to be exerting increased control over storm runoff.

Missoula Research Center

Since Packer's transfer and assignment to the Missoula R.C., virtually all of his time has been devoted to consideration of the watershed management problems in the R-1 territory. This has required considerable field travel and discussions with many people. The gross result to date is a long and varied list of potential research problems. These are now being sifted for inclusion in a research program.

NORTHEASTERN FOREST EXPERIMENT STATION

Division of Watershed Management Research

Semi-Annual Report October 1955

GENERAL

I'm not sure we got so much done the past six months--but we were awfully busy. Sid Weitzman labored along without a Project Leader until Ken Reinhart's recent arrival at the Fernow. At Kingston, Reigner and Eschner were bedevilled by drought, fire, and flood, in that order. Trimble's group at Hubbard Brook enjoyed their first field season on their new Experimental Forest. An enjoyable memory is the breath-taking dip with Storey, Wilm, Trimble, and Sartz into one of the deeper and colder pools of Hubbard Brook.

New Jersey Study

In April, we started weekly measurements of soils moisture content under five stand conditions at the Lebanon Experimental Forest. The soils are deep and sandy--mainly Evesboro sand; the five conditions included oak scrub, herbaceous, mature shortleaf pine, pine saplings, and pine reproduction. Soil moisture records will be interpreted in terms of opportunity for groundwater recharge. Samples have been taken with a soil tube to a depth of 5 feet with occasional forays to 11 feet. Sampling will end this winter after soil moisture recharge.

Northern New Jersey Watersheds

In May, Si Little and Lull paid a visit to East Orange's Water Reserve and Newark's Pequannock watershed. East Orange has a 2,200-acre Reserve in which it draws water from deep wells--over 5 million gallons a day. The Reserve, which is almost entirely forested, has an intensive fire protection system and management plan. Recharge areas have been developed over gravel and sand beds.

Newark utilizes all the streamflow from their 36,000 acre Pequannock watershed. Five reservoirs occupy about 2,000 acres. The watershed furnishes about 50 million gallons of water a day, about half of Newark's requirements. Watershed management involves largely protection: water value is dominant and sales of forest products are not encouraged. A three-man crew is kept busy cutting streambank vegetation and clearing channels to prevent coloration of water by decaying wood.

Water shortage is the major problem of this metropolitan area. According to one authority, the safe yield of underground and surface supplies for northern New Jersey is 480 million gallons per day; present withdrawal is 485 million gallons. Foresters in charge of both the East Orange and Newark watershed are keenly interested in methods of increasing yield. They are now considering our suggestions for yield and protection studies.

Appreciation

In getting Hubbard Brook underway, we have often sought the advice of others in setting up a program. Responses to our queries have been most generous. We have talked with Dick Hertzler, Howard Cook, Walter Langbeim; Hal Wilm kindly agreed to serve as a Station consultant and recently spent a week at Hubbard Brook; we have had two excellent memoranda from Henry Anderson and Ed Johnson concerning sedimentation and groundwater measurement, and have had correspondence with Jerry Dunford, Bert Goodell, and Marvin Hoover on streamflow and precipitation measurement. And, Herb Storey has been steadily pitching for us--for these and sundry other favors--our thanks.

Quotes:

Rushmore and Ash Hough have brought the following two timeless references to our attention:

> "There is great need of /streamflow/ records in order to discuss intelligently the effects of forest upon river flow, for while it is generally recognized that forest preservation has a beneficial influence, the extent of this influence has never been accurately determined, and there is wide diversity of opinion as to how far-reaching it is. On hardly any phase of forestry has there been more discussion than on this, and on hardly any is there so slight a basis of known fact on which to rest the argument. It is very necessary that a definite understanding be reached on this point, for on the available supply of water depend many of the greatest industries of the country."
>
> Frederick H. Newell. Bull 30.
> Div. of Forestry, USDA 1901

"The important fundamental rule to be observed in the location of a /forest/ road is, the grade should always be an easy one. A long road is safer, cheaper, and better than a steeper one. ....These roads should be properly ditched on the sides....and the breaks for the removal of water should not be more than 100 feet apart on an ascending road."

"The decreased flow of streams in Pennsylvania, the great demand made upon them for manufacturing purposes, and the pollution to which they are subject by reason of the increase of population and the multiplication of industrial establishments, are such unnatural conditions that it became necessary to devise some means by which the water supply might be made cleaner and more abundant, and kept so, as far as possible."

Report of the Pa. Dept. of Forestry, 1907

KINGSTON RESEARCH CENTER

The situation developed slowly at Dilldown. It rained now and then early in June and almost 2 inches on June 11 and 12. After that, the dry season began. The rest of June saw 0.34 inch of rain. By July 15, 0.11 more rain had fallen. On that day, Dixon Miller found the first fire on the watershed. A week later, with no more rain, but with plenty of heat and low humidity, the trouble began. The incendiary, apparently well informed, picked the hottest day of the summer to set three more fires on the watershed.

The Pocono Experimental Forest, although not exactly one of God's more favored spots, fared somewhat better than Dilldown. Only 16 miles away, and with a consistent record of 20 percent less rainfall than Dilldown, it was a little better watered in July. During the same time that 0.11 inch trickled on Dilldown, 1.87 inches of rain fell on the Pocono Forest.

It finally did rain, though, and not gently. Hurricanes Connie and Diane were blown out but not dried out by the time they reached the Poconos. Within seven days, the two hurricanes dumped 15.29 inches of rain on Dilldown and 19.98 inches on the Pocono Forest.

More later on the flood, but first:

The Fire

Smoke was first sighted by Gene McNamara on the afternoon of July 22. He called for help and went to the smoke. By the time help arrived, two more sets had been discovered, and none could be extinguished. The soils had become so dry that roots and stumps burned under-ground, smoldered indefinitely, and carried the fire to unburned areas. Even the humus at Dilldown, peculiarly fireproof, burned in some spots and exposed mineral soil.

The next day, Saturday, another fire was set, this time in the adjacent watershed of Mud Run Creek where most of the experimental plantings are located. Although the Penna. Dept. of Forests and Waters had numerous crews and bulldozers at work, considerable areas burned at all sets and lines could not be held. The local fire company responded to call and managed to save several buildings in the path of the fire. Finally, a bulldozer managed to get a line around the Dilldown fire about sundown.

That night it rained--all of 0.04 inch (0.73 at the Pocono Forest). Although the fires were not extinguished, even this slight amount allowed the crews to contain the fires.

Then began the exhausting task of patrolling--trying to hold the fires until enough rain fell to extinguish them. State crews from three districts made up the bulk of the manpower; but considerable support was given by leaders and older boys of three Boy Scout camps in the vicinity. This center rendered the small amount of assistance it could.

The monotony was punctuated by another set at the far end of Mud Run watershed on the sixth day, a shift in wind on the ninth day which carried the Mud Run fire to new areas, and the sixth set on the eleventh day.

A brisk wind on the twelfth day carried the Dilldown fire across its line and burned about 300 additional acres of the watershed before a new line could be bulldozed. Burning conditions were so bad by this time that the fire travelled swiftly even at night if fuel were available.

On the thirteenth day, the seventh set was discovered, near the stream-gaging station. Conditions were so desperate that Mike Ostrander and Wayne Banks from our Upper Darby office were dispatched to the fire and two men from the Allegheny National Forest arrived with a truckload of equipment on the fourteenth day.

These fellows had the right touch and brought 0.04 inch of rain on the fifteenth day, followed by 0.68 on the sixteenth day. The situation was good by then, and the fire was finally extinguished the following day, August 7, by more showers totalling 0.92 inch.

While the fire was quite small in comparison to western fires and the actual monetary damage was negligible, still the suppression costs were considerable, and the future of our watershed research is discouraging when the incendiary situation can be solved. Extremely dry summer conditions such as those experienced this summar are rare, probably occurring about once every 25 years. Fortunately, this fire came at the end of the calibration period.

The Flood

During the fire, it was often predicted that when the drought was finally broken, it would REALLY rain. How true!

The Friday after the fire, Hurricane Connie hit the Poconos. Rainfall at Dilldown totalled 9.06 inches; at the Pocono Experimental Forest it amounted to 8.33. This was an exceptionally large storm but no damage was experienced because the soil was so dry and groundwater so low that much of the rain could easily be stored.

But storage capacities were filled by Connie and along came Diane on the following Wednesday. Diane was a smaller storm at Dilldown, amounting to 6.23 inches of rain. Stream discharge, however, rose to a record height, somewhere close to 350 c.f.s. (146 c.s.m.). This was almost double the previous high discharge, the result of 9.30 inches of rain in July 1952. The damage at Dilldown was not great; roads suffered some washouts and a new emergency fire line eroded badly and carried some sediments toward (but not into) Dilldown creek.

The situation at the Pocono Experimental Forest was amazingly different! Connie was smaller, 8.33 inches and resulted in greater runoff than at Dilldown--apparently because the watershed has less storage capacity. But, Diane hovered over the Experimental Forest and dumped 11.65 inches; this was the high measurement for Pennsylvania according to Weather Bureau correspondence just received.

The peak stage at the streamgaging station was about 1.5 feet over the wing walls of the weir. Several small dams in the vicinity were breached and further downstream much damage was done.

The Stroudsburg disaster, well known to all, was the result of Diane's downpour on the eastern Poconos. The Broadhead Creek watershed, which delivered the damaging flood waters to the Stroudsburgs, is nearly all forested. A few days after the storm, sitting on one of Hazel's windfalls in the Pocono Experimental Forest, we looked at water-windrowed leaves under a sixty year old stand and mulled over our ideas of flood control. Certainly, forested watersheds will not prevent floods from storms of Diane's magnitude.

Watershed Calibration

Between the foregoing diversions and other sundry odd jobs developing from them, we have attempted to carry on our watershed calibration analysis. Several items of interest were discovered. To begin with we analyzed the relationships between annual precipitation and runoff, using raw data uncorrected for storage changes. Beginning the water-year of each of the 12 months, some of the correlations were remarkably high. The best correlation was obtained for the year beginning July 1, with a correlation coefficient of 0.995. Groundwater storage varied less on June 30 than at any other month end.

Later, after calculating the storage amounts (soil, groundwater, and snow) for each month end, we were able to determine an adjusted annual runoff for all years and beginning with each calendar month. That is, we have adjusted runoff for each year beginning January 1, for each year beginning February 1, and so on. With 6 complete years of data, we have 61 annual periods to work with.

Adjusted runoff for each period was plotted on a time scale, resulting, in effect, in a 12-month running average of runoff. When 12-month running averages of the various independent variables were plotted on the same time scale, relationships were easily discernible. Precipitation was closely correlated, as may be expected.

The effect of precipitation was removed by calculating the deviations from an equation using adjusted runoff as the dependent variable and precipitation as the independent variable. The deviations were plotted on the same scale and another pattern developed. This one showing a similarity with a plotting of saturation deficit.

A multiple regression was then calculated with saturation deficit showing up highly significant. The deviations from this regression still form a pattern which is not random variation.

A start was made to relate peak discharge to other measurable variables. An excellent relationship was obtained using simple storm precipitation. The relationship was improved by using the increase in discharge (peak discharge minus discharge at beginning of storm). The analysis has not progressed far, but it appears that antecedent precipitation will be a factor.

Streamgaging Station Maintenance

For some time we had been anxious to remove the sediment in the weir pool at the Pocono Experimental Forest. Actually the sediment was not great and was mostly light organic matter. Before we got to the job, however, Diane came along with a rather large amount of heavy sediment--rocks, gravel, and sand. Diane also upset an 800 pound concrete pillar which held the outside staff gage.

The weir, built in 1949, had never before been drained and we anticipated trouble in removing the drain plugs. The latter were threaded cast iron plugs turned into the downstream ends of the drain pipes. Much to our surprise, they were easily removed. We can highly recommend this arrangement; the plugs are very accessible, making the job of draining the pool quite simple.

The sediments were cleared from the pool and the gage pillar was reset with a new footing poured around it. At the same time a slab was installed in the streambed below the weir to facilitate current meter measurements.

A similar job must still be done at the Dilldown weir. The U.S.G.S. hydrographic engineers who generally furnish maintenance to this weir are swamped with repair work from Diane. We have volunteered to do the job.

Dilldown Report No. 3

April and May were devoted to preparing the third biennial report on the Delaware-Lehigh Experimental Forest (Dilldown Watershed). Although changes in personnel and center location precluded much analysis of piled up data, the report will include the usual climatic, groundwater, and streamflow tables, completing six years of published records. Also presented are discussions on each of the hydrologic factors and a detailed progress report on the scrub oak conversion studies at the Experimental Forest.

The publication has been edited and presented to the Pennsylvania Department of Forests and Waters for approval and publication.

Scrub Oak Conversion

Some years ago, we wrote a Station Note relating how we planted seedlings too soon after treating the site with herbicides and all or most of the seedlings died. We're in a rut--it happened again!

Spots treated with herbicides on March 10 and 11 were planted with red pine on May 9 to 12. We figured that two months should be plenty of time for the toxicity of the herbicide to be dissipated. We were primarily interested in growth, not in survival, but made provision to test for residual toxicity.

Sure enough, it is quite clear that the spots showing the best kill of the unwanted ground cover also have the fewest survivors. The heavy Ammate concentrations have fewer survivors than the lighter concentrations, and spots prepared with 2,4,5-T both in oil and water carriers have low survival rates. We will report more completely on this matter later.

Dilldown Conversion Plan

A plan for conversion of the scrub oak cover to tall-growing tree species was prepared by W. E. McQuilkin in July for the consideration of the Pennsylvania Department of Forests and Waters. The plan has been tentatively approved, pending discussion of planting schedules, and work will begin this fall on mechanically clearing 335 acres for planting next spring. As constituted, the plan entails a 5-year planting program to convert 1140 acres of the 1530-acre watershed.

Infiltration Project

Field work in the Northeast for the Vicksburg Infiltration project was completed in June. However, even before the end was in sight, Ralph Moyle was transferred to the Crossett Experimental Forest in Arkansas. Forestry aid Johnnie Lee, from Vicksburg, Mississippi, was detailed to Kingston for six weeks to assist in the final sampling rounds.

Soil identification at all sites in Pennsylvania, New York and New England has been completed with the cooperation of soil scientists of the S.C.S. in their various districts. Some of the physical properties of these soils have been determined and are to be published or otherwise made available to these cooperators. Eschner is attempting to correlate bulk density of soil with other, more easily measured, physical characteristics of the soil in an effort to make bulk density determination simpler.

Three additional study sites were set up on the University of Maine forest near Orono in cooperation with the Penobscot Research Center. These sites were visited twice by personnel of the infiltration unit and will be sampled daily for the rest of the summer by student assistants from Maine.

Upon completion of the field sampling schedule early in June, Johnnie Lee and Beryl Jones left for Vicksburg. Art Eschner remains at Kingston as a member of the center's staff.

Meetings

The Pocono Forestry Association annual meeting was attended August 17. The panel on "Forest Problems and Answers" revealed the increased pressure on forest land for flood control, hunting, fishing, timber production and scenic enjoyment. An additional $500 was voted for conviction of those setting forest fires maliciously thus bringing the reward to $1,000 in the Pocono region.

A series of meetings sponsored by the Pennsylvania Forestry Association have been scheduled to initiate the formation of local watershed groups. The program envisages several regional groups which will be subdivided into local watershed groups. The Brandywine Valley Association, with a successful ten-year record, is used as a model.

Howard and Reigner attended the second of the series, held in Stroudsburg on September 21. It was a very timely subject, coming so soon after the recent flood disaster. Many of those attending were under the impression the meeting was called to discuss the flood. Instead, it was a segment of a long-range program.

The same day, Howard and Reigner attended the first session of the Congressional Subcommittee hearings on the Hoover Report on Water and Power Resources. The sub committee will hold hearings in all regions to receive testimony from the citizens and organizations in those regions. Although a number of the witnesses were not familiar with the Hoover Report, general agreement was reached that the Middle Atlantic states have not been receiving their share of Federal expenditures for flood control. On other, more controversial issues, no agreement was reached.

MOUNTAIN STATE RESEARCH CENTER

Calibration is continuing on the five watersheds in which weirs were constructed in 1950. Plans have been made and sites selected for two new 120° V-notch weirs to be built this fall.

Representatives from nearly all the National Forests in Region 7, as well as many other public and private foresters, have by now visited the Fernow Forest to study truck and logging-arch road construction. Most have been impressed with the fact that even in steep country, it is not only possible but practicable to lay out roads with a grade of only 10 percent.

Visitors

The popularity of Weir No. 2 is growing by leaps and bounds. Visitors from as far away as Africa dropped in on us. In all, during the past 6 months we conducted 22 show-me trips involving over 225 visitors. Included were 50 Forest Service visitors, from both NFA and Research.

Meetings

Sid Weitzman attended the Supervisors' meeting, Region 7, and delivered a paper on "Integrating Timber and Watershed Management".

On September 23, Weitzman and Hutnik attended the West Virginia Chapter meeting of the SAF at Camp Caesar.

On September 24, Weitzman attended the S.C.S.A. meeting at Jackson's Mill, where he presented a paper on "Woodland and Watershed Management under West Virginia Conditions".

Personnel

Ken Reinhart left the hot Mississippi country-side and arrived over the Labor Day weekend; so the position vacated by Dick Trimble in October 1954 has finally been filled. Ken was previously with the Vicksburg Infiltration Project and is in the process of getting his feet wet in local watershed management problems.

WHITE PINE-HARDWOOD RESEARCH CENTER

The Hubbard Brook watershed was officially established as an Experimental Forest on May 17, 1955. The entire Hubbard Brook drainage has been explored in detail. Every foot of streambed has been examined for good gage sites. The condition of the cover and the boundaries of the subwatersheds have been looked into. Dick Sartz, who bore the brunt of this exploration, lost so much weight he now answers to the name of "Skinny".

Soil Survey

Field work on the soil survey of the Hubbard Brook Experimental Forest has been completed except for writing a few more profile descriptions. A joint report will be made with the Soil Conservation Service. Bob Pierce and the SCS surveyors are working up a soils map for the area.

Skid Road Revegetation Study

A skid road revegetation study was installed on the Bartlett Experimental Forest in August. The following seed mixtures are being tested--with and without lime and fertilizer treatment--on both badly eroded and slightly eroded abandoned skid roads:

(1) Barn chaff
(2) Rye
(3) Orchard grass
(4) Oats, timothy, and red top (equal portions by weight)
(5) 44% red fescue, 20% Kentucky blue grass, 20% red top, 12% domestic rye, 4% White Dutch clover (portions by weight)

Installations

A 90 degree V-notch weir has been installed on one of the Hubbard Brook subwatersheds. Precipitation measuring stations and a climatic station are also being installed. Considerable time will be devoted to winterizing the equipment and determining methods to use in measuring both runoff and precipitation during periods of extremely cold weather and heavy snow.

Hurricane Diane

Sartz and Trimble made a reconnaissance of flood damages in southwestern Massachusetts and northwestern Connecticut resulting from the heavy rainfall that was caused by Diane. From 10 to 20 inches of rain hit the area. Damage from flooding was terrific. Our survey was aimed at determining what happened in the wooded areas. We looked for evidence that man's activities--land use practices--had affected damages.

It was strikingly apparent that roads were the primary cause of erosion and sedimentation from wooded areas. All of the poor road practices we have preached about were evident and the results were startling. Steep, undrained roads gullied and washed, dumping tons of earth and rocks on highways, and in streams and ditches. Poorly located roads--roads too close to streams or which approached stream crossings from below or which were located in draws--became raging torrents as streams jumped their banks and washed out the road beds. Culverts and bridges--too far apart or of too little capacity--plugged or washed out. On the other hand, the few good woods roads we saw appeared to have stood up reasonably well, considering the ferocity of the storm. Good locations and adequate drainage provisions paid off. Another noticeable fact was that well vegetated old road beds, banks, and shoulders eroded little under heavy surface runoff except where they were hit by a head of water. Earth slides were frequent along both streams and roads on very steep slopes--even in places which were well forested. Stream bank cutting and scouring happened frequently; it appeared to be especially prevalent where the stream banks had been encroached upon by roads. On some very steep forested slopes--on grades above 65 percent--there was some evidence of overland flow even where the forest floor was in good condition.

In addition to serving as source areas of sediment, the poor forest roads undoubtedly acted to concentrate runoff, thus aggravating the flood situation.

Snow Study

Results from the snow study at the Bartlett Experimental Forest, described in the last semi-annual report, are as follows:

1. The interception of snow (in terms of water equivalent) by a bare hardwood canopy was confined largely to the area beneath the crowns. In openings in the forest, the interception effect was not felt beyond a distance between 5 and 20 feet from the edge of the canopy, and even within this variable belt it was slight.

2. The snow pack in the open contained the greatest amount of water. Pole-sized hardwood stands intercepted more snow than sawtimber stands. Average accumulated interception of snow water (at time of maximum snowpack) in pole stands was about 10 to 12 percent. Sawtimber stands intercepted about half as much water as the pole stands.

3. Density of the snow under the hardwood canopy was consistently greater under both pole and sawtimber stands than in the open at maximum snow pack. This difference persisted well into the melt period.

4. Snow disappeared first in the unshaded open; next under canopy; and last from a narrow shaded belt near the southern boundaries of the plots; i.e., in the open near the north edge of the timber. This resulted from the higher accumulated snow water in the open and the lower rate of melt due to shading from the nearby forest canopy.

5. The snow pack apparently began to lose water by melting when the snow density reached about one-third or when 3 inches of snow contained about one inch of water.

6. Snow melt at the tree trunks extended in ever-widening circles of bare ground as the melt period progressed.

7. This study indicated that to catch the maximum amount of snow and to delay its melt as long as possible, narrow openings running in an east-west direction should be made. The most effective width of the cuttings would depend on latitude, aspect, grade of the land, and height of the trees. These factors affect the angle of incidence of the sun's rays and the amount of direct solar radiation reaching the snow surface. On steep north-facing slopes in tall timber, relatively wide strips could be used effectively. On 10 to 15 percent north-facing slopes with 60- to 70-foot high trees, a strip about 30 to 40 feet wide appears to offer enough shade to delay snow melting beyond the time snow disappears in both the unshaded open and under canopy. These figures are tentative; more study over a longer period would be necessary to establish firmer relationships.

Soil Freezing Study

Bob Pierce, Howard Lull, and Herb Storey have completed a rough draft of a manuscript on soil freezing which summarizes two winters' field work in the Northeast. The field work was done under the direction of Herb Storey when he was with the Station. The manuscript shows the effect of various types of forest cover and conditions on the occurrence and depth of impermeable soil freezing.

Bob Pierce will present a paper at this year's Eastern Snow Conference covering the highlights of the frost study manuscript.

Meetings

Jensen and Trimble attended the annual meeting of The Connecticut River Watershed Council at Amherst, Massachusetts in April. Trimble participated in a panel discussion on watershed management research with Lull and Wilm.

Jensen and Trimble attended the first meeting of the New England Watershed Conference in Peterborough, New Hampshire in August. Emphasis was on water scarcity and conservation. Ironically enough, the hurricane Diane floods struck during the conference--"food for thought".

Visitors

Les Harper, Ralph Marquis, and Chick Mattoon were Forest Service visitors at the Hubbard Brook Experimental Forest this summer.

Ed Johnson dropped in but we are sorry to say we were too deep in the woods for Ed to find us.

Bud Foster, secretary of the Connecticut River Watershed Council, was up for a visit.

A week-long program planning conference was held in July at Hubbard Brook. Participating, along with local personnel, were Hal Wilm, Herb Storey, and Howard Lull. This was a most helpful meeting.

PUBLICATIONS

Watershed Research Begins in New Hampshire by George R. Trimble, Jr. Forest Notes 46:22-25. Summer, 1955.

Skidroad Erosion--A Byproduct of Mechanical Logging by Richard S. Sartz, Northeastern Logger 4 (1):10-11. 1955.

Water Supplies and Our Forests by Howard W. Lull. Pennsylvania Forests 45 (3):58-60. Summer, 1955.

PACIFIC NORTHWEST FOREST AND RANGE
EXPERIMENT STATION

Watershed Management Research
Semiannual Progress Report, April 1 - September 30, 1955

General

On July 1, 1955 a Division of Watershed Management Research was formed in the Pacific Northwest Forest and Range Experiment Station. It is the culmination of many years of effort by many people.

One of the first jobs was recruitment of personnel. This has proven to be a frustrating and time-consuming chore. At least thirty possible candidates have been contacted and to date one technical man has been hired for watershed research. We are negotiating with two other likely possibilities and, if they are hired, the originally planned openings will be filled. The need for still another recruit will soon develop when final agreement for a cooperative research project is made with the City of Portland.

Cooperative Research

We have made good progress in our efforts to get funds from outside sources to conduct research on a cooperative basis. Best progress has been made with the Portland Water Bureau. Finishing touches are being put on a cooperative agreement which is soon to be considered by the City Council. Many unforseen delays have developed but eventual success seems certain. This cooperative arrangement will be the second important milestone for the Division of Watershed Management in this Station.

A second cooperative agreement involving forest, range and watershed research is being negotiated with the owners of Pilot Rock Lumber Company in Oregon's Blue Mountains. This company is interested in management of lodgepole pine lands of which they own considerable amounts. Their interest includes forage and water resources and they have virtually agreed to help support a research position in the Blue Mountain Research Center.

A third likely possibility was explored in the Mid-Columbia Research Center area. A large company operating in pine and mixed conifer types in the Yakima area has shown considerable interest in expanding the scope of local research. They own a large amount of land with combined timber, forage, and water values represented. Some of these holdings are in drainage supplying domestic water for the City of Ellensburg. The company has not yet done any logging in this watershed but plans to do so in the next few years. They feel the need for some guidance before starting their logging program.

Meagher, Garrison and Dunford visited some of their logged-over lands, current cutting operations and virgin stands in August. The intent was to examine problems needing research and possibilities of setting up a small experimental forest on company lands. Next step will be preparation of a proposed research program which we can present to the company as a basis for a cooperative venture.

Willamette Research Center

On the H. J. Andrews Experimental Forest preliminary plans are being made for a test of the Wyssen Skyline Crane. In June, Jacob Wyssen looked at Experimental Watershed No. 2 to determine its suitability for demonstration purposes. Arrangements are now being made for sale of the timber in a manner that will assure Wyssen a reasonable return on the cost of developing a machine large enough to handle Douglas-fir.

Provisions are being made for measuring sediment movement from all three of the small watersheds. A debris basin has been constructed below the flume in one drainage and two others will be completed this fall.

In late August, Gerhard F. Muerle was transferred from the Siskiyou National Forest to become officer in charge of H. J. Andrews Experimental Forest. He fills the position temporarily vacated by Richard C. Koenig who is on educational leave. This position is now a joint forest management-watershed management assignment with support shared equally by those two functions.

A study is being conducted in cooperation with the Soils Department of Oregon State College to determine the effects of logging and slash burning on soil erodibility in the Corvallis Watershed. The work is being done by a graduate student majoring in forest soils. Soil samples were taken in a number of clear-cut patches before and after slash burning and in neighboring uncut areas to compare physical properties which are related to erosion. Laboratory work will continue through the winter and some results are expected in early spring.

Blue Mountain Research Center

During the summer sample plots were established in the areas draining into debris basins. Each drainage contains ten permanent transects: five in the grass type and five in timber type. The over-all objective of both debris basins and transects is to determine the effect of grazing intensity on erosion of summer ranges. Each transect is a cluster of seven reference points at which data on herbage production, forage utilization and soil cover are measured. Soil measurements include estimates of the area covered by litter, area of exposed mineral soil, area covered by rock, and size of maximum soil opening. Measurements will be made of these factors every three years.

A search was made this summer in the Starkey Experimental Forest and Range to locate a pair of watersheds suitable for research purposes. Two desirable drainages were found with cover consisting of mixed conifer, pure lodgepole pine and grass.

Mid-Columbia Research Center

In July, Dunford and Garrison looked at much of the national forest land in the Mid-Columbia Research Center for test watersheds. They traveled by car, air and horseback. The drainages previously proposed in the Entiat River watershed were examined in considerable detail and still remain the best possibilities. Desirable sites have proven difficult to find in the area because the topography is extremely rugged and the geologic development is relatively youthful.

Miscellaneous Activities

Our plans for watershed research have been presented before various meetings during the last six months. These include the Region 6 Investigative Committee, the Columbia Basin Interagency Committee, the Washington Forest Practice Committee of the Western Pine Association, the Station's Research Advisory Committee and the Portland Chapter of the Columbia River Section, SAF.

Dunford has had to devote considerable time to preparation of technical papers. The three most important are his assignment for the Watershed Management Conference, a talk for the Watershed Management Division of the SAF at their annual meeting; and a contribution to a proposed manual on methods and techniques in range research.

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Division of Watershed Management Research

Semiannual Report -- April 1, 1955 - October 1, 1955

Tempe

Work at Sierra Ancha this summer was primarily concerned with completing the basal spraying of chaparral shrubs on the two 12 acre Natural Drainage watersheds. One watershed was treated during the summer of 1954 and a very good kill appears to have taken place. Another 12 acre watershed was sprayed during the past summer using a 5 percent solution of brushkiller containing equal parts of 2,4-D and 2,4,5-T (2 pounds acid equivalent of each per gallon) in a diesel oil carrier to the basal 6 to 8 inches of all live stems.

From the treatments so far applied it appears that there is little difference in the effectiveness of the basal spray during different seasons of the year. It appears that a high degree of top kill will result the first year. On the watershed sprayed last season some root sprouts of turbinella oak have appeared during the first growing season and it is anticipated that a few more will reappear during the second growing season. It now appears that a repeat treatment applied after the second season will be necessary to get a complete kill. Other species that have sprouted include redberry buckthorn, desert ceanothus and lemonbush. However, these do not appear to have sprouted as vigorously as the oak.

This poison treatment was applied to two complete watersheds. Streamflow from these two watersheds, which now have a predominantly grass cover, will be compared with that from two adjacent watersheds having a predominantly shrub plant cover. We hope to be able to determine whether or not chaparral shrubs seriously interfere with water yield under these particular soil and climatic conditions.

Timber harvest on the South Fork of Workman Creek was approximately 75 percent complete last September, but because of financial difficulties the operator has been unable to complete the cutting operation so far this summer. With a new operator now on the job it is hoped that we will be able to complete this cutting during the current season. We have had several inquiries about Workman Creek from several who attend jury meeting.

An agreement has been entered into with Region 3 to learn how partial cutting in mature ponderosa pine influences (1) annual and seasonal water yield; (2) peak runoff rates during spring snowmelt and from summer thunderstorms; and (3) sediment transported by streams. The trend of changes in water yield, flood peaks, and sediment movement with time after logging will be determined. Some measure of the length of time that partial cutting will affect watershed values will be determined.

The area of each watershed selected is approximately 1,000 acres at an elevation of about 8,000 feet. The timber is almost exclusively ponderosa pine, predominantly mature and overmature age classes. The net volume per acre is estimated at 8.2 M b.m. per acre. Sharp crested, 120° V-notch weirs will be used to measure the flow and a continuous record of water stage will be obtained by water-level recorders.

Sediment will be measured in two ways. The heavier material moving as bed load will be trapped in the upper basin of the stream gage and will be periodically measured and removed. The finer particles carried in suspension will be sampled by obtaining a continuous aliquot of streamflow. A very small sample of water will be continuously led into a storage container where the dry weight of the sediment will be determined. This study should give us some information on how timber cutting practices influence the amount of water, flood peaks, and sediment from ponderosa pine stands.

A four-way memorandum of understanding between the Arizona Game and Fish Department, Salt River Valley Water Users' Association, Tonto National Forest and the Experiment Station is being negotiated to study the changes in vegetation brought about by various methods of reducing shrub density on chaparral covered lands and to determine how these changes affect wildlife populations, water flows and sediment. The studies will be carried out on four small watersheds, each watershed being equipped with streamflow gaging devices. After a period of calibration the shrub cover on three of the watersheds will be reduced by practices such as chemical spraying, burning or mechanical removal. Measurements will be made and records kept to determine the effect these treatments have on water and sediment and whether game populations will build up under brushland management. If so, which of the treatments are most satisfactory for manipulating the cover to increase game production.

Grand Junction

In June 1955 a study was started on Black Mesa, Colorado, to determine relative water use by spruce, aspen, Thurber fescue, Idaho fescue, oak brush (Quercus gambeli) and oak brush-herbaceous types. These types cover extensive areas in western Colorado at elevations between 7,500 and 10,500 feet. Measurements of soil moisture were made at the beginning of the 1955 growing season on three or four sites in each type. At the end of the growing season soil moisture will be re-measured on the same sites, and the difference in moisture content will represent the total water loss resulting from transpiration, evaporation and interception.

Gravimetric measurements were taken in one-foot layers to a depth of eight feet. Bulk density of each layer was also determined to permit computation of the inches of water in each one foot of soil.

Spring and fall soil moisture measurements on these sites are planned for at least one more year.

Observations of the abundance and size of roots were made on 22 sites as a part of the study. These are summarized as follows:

1. Abundance and depth of penetration of spruce and aspen roots were found to be similar, i.e. abundant to 3 feet, scattered 3-5 feet, scarce to none 5-7 feet.

2. Oak brush roots penetrated deeper than spruce and aspen roots, although roots of all three tree species were either non-existent or very scarce below seven and a half feet.

3. Spruce roots were larger than the others near the surface, however below 30 inches oak brush roots were larger than either spruce or aspen.

4. Thurber and Idaho fescue roots both penetrated to six feet, however Thurber fescue roots were more abundant at all depths than Idaho fescue.

5. Roots in the oak-herbaceous type (mostly big sagebrush) were similar to Idaho fescue in abundance and depth of penetration.

The first steps toward a long-term watershed management program on Black Mesa are being taken this fall. Construction of two weirs is now underway, and we hope that these will be completed in time to measure runoff from next spring's snowmelt. A third weir will be built next summer in the same general area.

These installations will measure water yield and sediment production from small watersheds (100-200 acres) which are part of the Black Mesa experimental ranges. Comparisons will be made to determine the effect of grazing management and range condition. The elevation is about 9,000 feet and plant cover types are Thurber fescue, Idaho fescue, aspen, and spruce-fir.

Fraser Hydrologic Laboratory

Logging of the Fool Creek watershed, scheduled to be completed this fall, will not be completed until the field season of 1956. Shortage of labor was one factor necessitating a request by the cooperator for a time extension. Another factor was the contract stipulation that sub-sawlog size material be cut, bucked, and piled for sale as pulpwood. This local innovation under contract conditions proved unprofitable to the woods labor. About three-fourths of the scheduled cutting will be completed by close of operations this fall.

Thirteen years of record of streamflow from two watersheds differing markedly in size reveal an interesting relationship between peak discharge per unit area and drainage area. Fool Creek, draining a watershed only about one-third the size of that drained by East St. Louis Creek, has produced peak discharges per unit area that are equal to those from East St. Louis. This year's records from the three streams now being gaged at Fraser show the following relationship between watershed area and peak discharge per unit area:

Watershed	Area	Peak Discharge	
	sq. mi.	c.f.s.	c.f.m.
East St. Louis	3.1	18.6	6.0
Fool	1.1	6.8	6.0
Deadhorse	1.0	3.5	3.5

Annual peak discharges from these high altitude streams are consistently produced by snowmelt alone. However, it would be logical to expect that the smaller the watershed the more simultaneous would be the melting of the snow on the area. This, in turn, should cause a greater rate of runoff per unit area and a relationship between watershed area and peak discharge similar to that normally occurring when such discharges are caused by rainstorms. The meagre evidence here presented indicates that such reasoning is fallacious. Further years of record and analyses of data from other high mountain streams will test the validity of the relationship so far observed and may lead to the explanation.

During 1954 three recording rain gages were so placed as to yield data on how quantity and intensity of rainfall vary with elevation. In July, 1955, occurred one of the heaviest of storms recorded on the Fraser Forest. At Headquarters, elevation 9,000 feet, 1.35 inches of rain fell. At an elevation of 11,000 feet, the rainfall was 2.15 inches. Rainfall amounts and intensities have been consistently greater at the higher elevations, the peak for the latter being about 3.5 inches per hour for five minutes.

The winterizing of stream gages is being attempted this year in an effort to obtain continuous, year-long records. The greatest obstacle to previous attempts has been the freezing of water in the stilling well with immobilization of the float. To prevent this occurrence small heaters fueled by bottled gas are being installed in each stilling well. It is reasoned that the heat supply can be small; all that is required is the maintenance of an air temperature in the well sufficient to prevent loss of heat from the water to the air and to compensate for heat loss through the culvert pipe or concrete walls of the well.

The unit to be tried consists of a hog tank heater equipped with a thermo-couple operated safety valve and connected to a trailer size bottle of natural gas. The heater itself will be mounted a short distance above the maximum expected autumn water level so as to supply

heat most directly where needed. Since to our best knowledge water levels consistently drop slightly and steadily all winter, the gas flame will remain safely above the water surface until the sustained spring rise starts. With this event there is no further danger of freezing of the well and the heater will be removed until fall.

A stream gaging station on Lexen Creek, a 330 acre watershed, is currently under construction and will be finished this fall. A worthwhile innovation was the use of a back-hoe to do the major portion of the excavation. Another apparently successful step was the use of a mixture of old beaver pond sediment (mainly silt) and commercial Bentonite clay in proportion of 10 to 1 for back filling along the upper side of the cut-off wall. The soil and clay were combined in a cement mixer and placed dry. Tests indicated the mixture packed readily into an impervious mass. The time for backfilling was greatly reduced over that required by the use of locally dug clay in plastic condition.

Front Range

Estimating Runoff in Small Watersheds

The problem investigated was whether infiltration data, obtained with the Rocky Mountain infiltrometer, could be used to estimate surface runoff from high intensity summer storms on small watersheds covered with second growth ponderosa pine.

This study was limited to six small ponderosa pine watersheds on the Manitou Experimental Forest. Infiltration, precipitation (rainfall) and runoff (stormflow) were measured. During 1947, infiltration data were obtained from a total of 72 infiltrometer plots, 12 on each watershed. Rainfall data were limited to 21 high intensity summer rain storms, occurring from 1940 to 1947. Runoff data were limited to the same 21 storms. During the summer of 1948, the pine trees were removed from four of the watersheds, leaving two in their former condition. Seven rain storms occurring on the two undisturbed watersheds from 1948 to 1954 provided additional data for use in the present study.

Experimental technique

In order to estimate the runoff produced per storm on each watershed, it was necessary first to estimate the rainfall excess for each watershed. The estimate of rainfall excess was made by placing the storm pattern over the weighted infiltration curve of each watershed. The area of that portion of the storm pattern above the infiltration curve constituted the rainfall excess. The placement of the vertical axis of the infiltration curve in relation to the vertical axis of the storm pattern has a direct effect on the estimated rainfall excess.

Several different methods of locating the vertical axis of the infiltration curve in relation to the storm pattern were tried. Initially, figures for retention and interception were derived for each watershed and the net amount was subtracted out of the storm. This was accomplished by taking out the total amount of rainfall per first 5 minutes, plus the amount per second 5 minutes, etc., until the total additive amount equaled the net retention-interception figure, then the axis of the infiltration curve was placed at that point, on the horizontal axis of the storm pattern, where rainfall satisfied this retention-interception figure. This method was questionable due to the fact that the infiltrometer measures retention and in plotting the infiltration curves this measure of retention is accounted for. To use another measure of retention would mean doubling the amount of retention.

Another method of locating the infiltration curve relative to the storm pattern was to superimpose one axis directly over the other. This gave satisfactory estimates of rainfall excess for storms with the peak rate of rainfall occurring within the first 10 minutes of the storm. For storms with peaks occurring between 10 and 30 minutes, the estimated rainfall excess was too high.

For storms with peaks occurring after the first 10 minutes the vertical axis of the infiltration curve was placed at a point 5 minutes before the maximum burst or peak of the storm. This method, in combination with that described in the preceding paragraph produced usable estimates of rainfall excess.

Infiltration curves developed from the use of the Rocky Mountain infiltrometer are the result of applying rain at the rate of 4.5 to 5.5 inches per hour for a 50-minute period. Each 10-minute interval has the same intensity of rainfall applied. With these intensities, runoff starts usually within the first 5 minutes of rainfall application. With lower intensities a longer interval of time would pass before runoff starts. Thus, the placement of the vertical axis of the weighted infiltration curve for each watershed in the manner suggested above, coincides with the techniques used to develop the curve, as the highest intensity of a storm must first occur before runoff starts.

Analysis of rainfall excess and actual runoff

The estimated rainfall excess and actual runoff for 21 storm events on the six watersheds were fitted, by the least squares method, to a linear regression equation. The equation for the data of this study was:

$$1) \quad \hat{Y} = 0.0491X + 0.0049$$

where X = estimated rainfall excess

$\hat{Y}$ = estimated runoff

The coefficient of correlation between estimated rainfall excess and actual runoff was r = 0.4170, which was highly significant, i.e., to the 1 per cent level. The standard error of estimate was $S_{y.x}$ = 0.0102.[1] Individual estimates of runoff showed considerable variation, both within and between watersheds. The data of watersheds A and F gave underestimates of runoff, while those from watersheds B, C, D, and E gave overestimates of runoff. This is illustrated in Table 1. The mean estimated rainfall excess for the six watersheds, 0.0802, was roughly 10 times greater than the mean actual runoff, 0.0088. The relationship of the data is illustrated graphically in Fig. 1.

As a means of checking the reliability of the regression equation, $\hat{Y}$ = 0.0491X + 0.0049, it was applied to the 7 storms which occurred on watersheds B and D from 1948 to 1954. The results are given in Table 2.

Table 1.--MEAN VALUES OF RAINFALL EXCESS, ACTUAL RUNOFF, AND ESTIMATED RUNOFF, BY WATERSHEDS. (21 storms)

(Values of estimated runoff obtained with regression equation number 1.)

Watershed	Rainfall excess (inches)	Actual runoff (inches)	Estimated runoff (inches)
A	0.0529	0.0180	0.0075
B	0.0790	0.0042	0.0088
C	0.1216	0.0065	0.0109
D	0.0659	0.0064	0.0081
E	0.0507	0.0071	0.0074
F	0.1110	0.0106	0.0104
Mean	0.0802	0.0088	0.0088

The chi-square test was employed to determine the relative agreement between the estimated values of runoff and the actual values of runoff. The chi-square values for watershed B (χ^2 = 0.0292), and watershed D (χ^2 = 0.0246), each with 7 degrees of freedom, indicate the probability of obtaining a larger chi-square is less than one chance in a hundred. For such low values of chi-square there is indication that the estimated runoff values are in close agreement with actual runoff values.

[1] All figures of rainfall excess, rainfall, and actual runoff are in inches.

Table 2.--COMPARISON OF ESTIMATED RUNOFF WITH ACTUAL RUNOFF FROM SEVEN STORMS ON WATERSHEDS B AND D.

(Estimated runoff obtained with regression equation number 1.)

Storm	Watershed B				Watershed D			
	X[1] inches	Y[2] inches	Y[3] inches	χ^2[4]	X inches	Y inches	Y inches	χ^2
8/5/48	0.0000	0.0001	0.0049	0.0047	0.0000	0.0002	0.0049	0.0045
7/11/49	0.0624	0.0049	0.0080	0.0012	0.0312	0.0022	0.0064	0.0028
7/11/50	0.0087	0.0006	0.0053	0.0042	0.0021	0.0022	0.0050	0.0016
8/8/52	0.0000	0.0002	0.0049	0.0045	0.0000	0.0000	0.0049	0.0049
7/8/53	0.0417	0.0004	0.0069	0.0061	0.0154	0.0023	0.0057	0.0020
8/7/54	0.0033	0.0004	0.0051	0.0043	0.0000	0.0004	0.0049	0.0041
8/23/54	0.0075	0.0006	0.0053	0.0042	0.0000	0.0001	0.0049	0.0047
Mean	0.0177	0.0010	0.0058		0.0070	0.0011	0.0058	
Total				0.0292				0.0246

[1]X = estimated rainfall excess
[2]Y = actual runoff
[3]Y = estimated runoff
[4]χ^2 = chi-square value

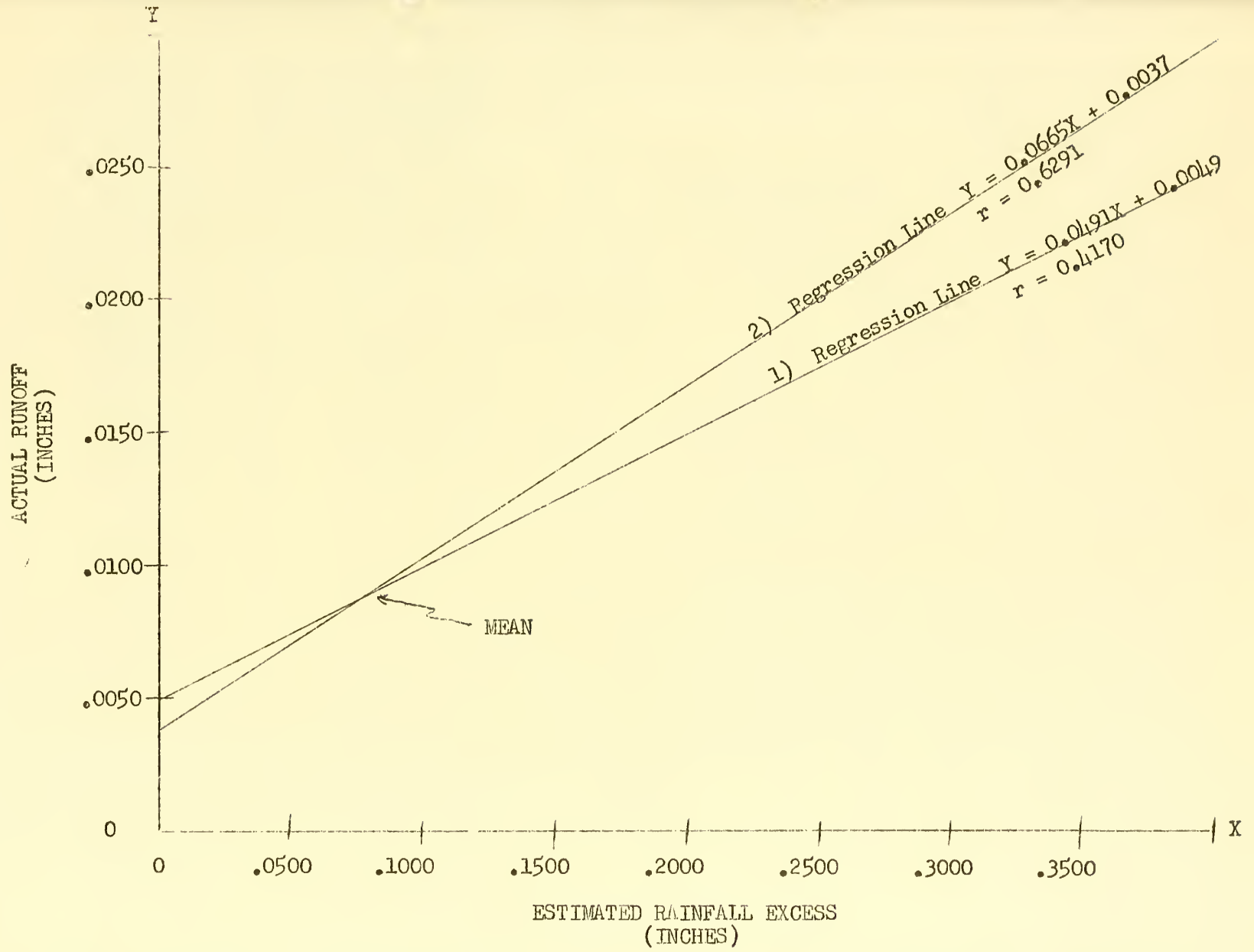

Fig. 1.--Relation of estimated rainfall excess to actual runoff, as determined by regressions 1 and 2.

Analysis of actual runoff

In an attempt to explain the variation encountered in the estimates of surface runoff, the actual runoff of the individual watersheds was subjected to an analysis of variance. This analysis would determine whether the individual watersheds differed significantly, with respect to the amount of runoff produced per storm.

It was found that the watersheds differed significantly, with respect to actual runoff. This is illustrated by the analysis of variance in Table 3.

Table 3.--ANALYSIS OF VARIANCE OF ACTUAL RUNOFF FROM THE SIX EXPERIMENTAL WATERSHEDS.

Source of variation	Sums of squares	Degrees of freedom	Mean squares	F
Blocks[1]	0.000020	1	0.000020	0.23
Watersheds	0.002738	5	0.000548	6.23[2]
Error	0.009920	113	0.000088	
Total	0.012678	119	0.000107	

[1] Watersheds A, B, and C constituted Block I; watersheds D, E, and F constituted Block II.

[2] Significant beyond the 1% level.

In an effort to determine which watersheds were different, with respect to the amount of runoff produced per storm, the "t" test was employed. The results of this analysis are given in Table 4. It was found that the runoff from watershed A differed significantly from the runoff of the other five watersheds. The runoff from watershed F differed with the runoff from watersheds A and B significantly; watersheds B, C, D, and E were essentially the same, with respect to actual runoff produced per storm.

Analysis of average rainfall excess and average actual runoff

To reduce the large standard error of estimate, noted in the use of regression equation 1, and to overcome the variation of actual runoff from the individual watersheds, the data for the six watersheds were pooled and an average figure for estimated rainfall excess and actual runoff was derived for each of the 21 storms involved. These data were fitted, by the least squares method, into the following regression equation:

2) $\hat{Y} = 0.0665X + 0.0037$

where X = estimated rainfall excess (average)

$\hat{Y}$ = estimated runoff (average)

Table 4.--COMPARISON OF THE SIX EXPERIMENTAL WATERSHEDS, WITH RESPECT TO RUNOFF PRODUCED PER STORM.

(The comparisons listed in this table were obtained through the use of the "t" test.)

Watershed	A	B	C	D	E	F
A vs.	-	HS[1]	HS	HS	HS	S[2]
B vs.		-	NS[3]	NS	NS	S
C vs.			-	NS	NS	NS
D vs.				-	NS	NS
E vs.					-	NS
F vs.						-

[1]Highly significant, i.e., significant to the 1% level.
[2]Significant, i.e., significant to the 5% level.
[3]Non-significant, i.e., not significant to the 5% level.

The coefficient of correlation between average estimated rainfall excess and average actual runoff was $r = 0.6291$, which is highly significant, i.e., to the 1 per cent level. The standard error of estimate was $S_{y.x} = 0.0073$.

The above equation, $Y = 0.0665X + 0.0037$, was employed to estimate the runoff from watersheds B and D for the 7 storms occurring from 1948 to 1954. The results are given in Table 5.

The chi-square test was employed to determine the relative agreement between the estimated values of runoff and the actual values of runoff. The chi-square values for watershed B, $\chi^2 = 0.0230$, and watershed D, $\chi^2 = 0.0175$, with 7 degrees of freedom for each, indicate the probability of obtaining a larger chi-square value is less than one chance in a hundred. Such low values of chi-square indicate that the estimated runoff values are in close agreement with the actual runoff values.

Analysis of rainfall excess, total rainfall, rainfall for first thirty minutes of storm, and actual runoff

Estimated rainfall excess, total rainfall, and rainfall for the first 30 minutes of the storm were related to actual runoff through the use of multiple regression, in an attempt to improve the method of

Table 5.--COMPARISON OF ESTIMATED RUNOFF WITH ACTUAL RUNOFF FROM SEVEN STORMS ON WATERSHEDS B AND D.

(Estimates of runoff were obtained with regression equation number 2.)

Storm	Watershed B				Watershed D			
	X[1] inches	Y[2] inches	Y[3] inches	χ^2[4]	X inches	Y inches	Y inches	χ^2
8/5/48	0.0000	0.0001	0.0037	0.0035	0.0000	0.0002	0.0037	0.0033
7/11/49	0.0624	0.0049	0.0078	0.0011	0.0312	0.0022	0.0058	0.0022
7/11/50	0.0087	0.0006	0.0043	0.0032	0.0021	0.0022	0.0038	0.0007
8/8/52	0.0000	0.0002	0.0037	0.0033	0.0000	0.0000	0.0037	0.0037
7/8/53	0.0417	0.0004	0.0065	0.0057	0.0154	0.0023	0.0047	0.0012
8/7/54	0.0033	0.0004	0.0039	0.0031	0.0000	0.0004	0.0037	0.0029
8/23/54	0.0075	0.0006	0.0042	0.0031	0.0000	0.0001	0.0037	0.0035
Mean	0.0177	0.0010	0.0049		0.0070	0.0011	0.0042	
Total				0.0230				0.0175

[1]X = estimated rainfall excess
[2]Y = actual runoff
[3]Y = estimated runoff
[4]χ^2 = chi square value

estimating surface runoff. The regression equation obtained is as follows:

$$3)\quad \hat{Y} = 0.00016X_1 + 0.00020X_2 + 0.00215X_3 + 0.00710$$

where X_1 = estimated rainfall excess per storm per watershed

X_2 = total rainfall per storm per watershed

X_3 = rainfall for first 30 minutes of storm, per watershed

$\hat{Y}$ = estimated runoff per storm per watershed

The multiple correlation coefficient was R = 0.6022. The standard error of estimate was $S_{y.123} = 0.0088$. The correlation between rainfall excess and actual runoff, as given in Table 6, was $r_{y1} = 0.4170$. The correlation between total rainfall and actual runoff was $r_{y2} = 0.5093$. The correlation between rainfall for first 30 minutes of the storm and actual runoff was $r_{y3} = 0.6014$.

It will be noted that none of the correlation coefficients involving Y (actual runoff) are as high as the correlation coefficient of average estimated rainfall excess and average actual runoff.

Supplemental analyses

Total 7-day antecedent rainfall was used as a variable, in combination with rainfall excess, total rainfall per storm and actual runoff, in multiple regression. Antecedent rainfall had a non-significant correlation with actual runoff.

Rainfall excess, total rainfall and actual runoff were embodied in a multiple regression, which resulted in a multiple correlation of R = 0.5636 and a standard error of estimate of $S_{y.12} = 0.0092$. The correlation between rainfall excess and total rainfall was $r_{12} = 0.5782$ and the correlation between total rainfall and actual runoff was $r_{y2} = 0.5121$. The correlation between rainfall excess and actual runoff was $r_{y1} = 0.4192$.

Rainfall excess and actual runoff data for watershed A, 21 storms, were fitted, by the least squares method, into a regression equation. The resulting equation was:

$$4)\quad \hat{Y} = 0.1244X + 0.0114$$

where X = estimated rainfall excess

$\hat{Y}$ = estimated runoff

The correlation coefficient for rainfall excess and actual runoff was $r = 0.6877$, and the standard error of estimate was $S_{y.x} = 0.0086$. The mean actual runoff was 0.0180.

Table 6.—CORRELATION OF VARIABLES USED IN MULTIPLE REGRESSION; RAINFALL EXCESS (X_1), TOTAL RAINFALL (X_2), RAINFALL FOR FIRST THIRTY MINUTES OF STORM (X_3), AND ACTUAL RUNOFF (Y).

	Variables			
r's	X_1	X_2	X_3	Y
r_{12}, r_{13}, r_{y1}	-	0.5787[1]	0.6818	0.6170
r_{23}, r_{y2}		-	0.8173	0.5093
r_{y3}			-	0.6014

[1]All figures are highly significant, i.e., beyond the 1% level.

Discussion

The results of this study indicate that surface runoff may be estimated through the use of a regression equation employing rainfall excess estimates as the variable.

Rainfall excess estimates were obtained by the manipulation of infiltration curves, derived from infiltrometer data, on storm intensity-graphs. It was assumed that the estimated rainfall excess obtained did not represent the amount of surface runoff that would appear at the gages of the watersheds. The excess would represent the amount of rainfall which did not infiltrate into the soil at a particular point, but would only contribute partly to the total surface runoff. A portion of the excess would remain as surface storage and either be infiltrated or evaporated later on. As it moved down slope some of the excess would be eliminated by channel absorption. In this study, actual runoff amounted to only 1/10 of the estimated rainfall excess. This is contrary to work reported by Woodward and Craddock in estimating flood potential. They stated in part, that the area within the storm pattern above the infiltration-capacity curve represented precipitation excess that would run off.

An initial regression equation, involving estimated rainfall excess and actual runoff, was developed for the six experimental watersheds. The individual estimates of surface runoff, when compared with actual runoff figures, showed considerable variation. For 124 storms, the relation between estimated rainfall excess and actual

runoff accounted for only 16 per cent[1] of the variation in runoff from the 21 individual storms.

It was suspected that the actual runoff from the individual watersheds differed considerably, which would explain the variation experienced in the estimates of runoff. This suspicion was borne out by an analysis of variance of actual runoff from the six watersheds. Furthermore, the "t" test indicated watershed A differed from the other five watersheds and watershed F differed from watersheds A and B, with respect to the actual runoff produced by each storm. This variation in runoff from storm to storm and from watershed to watershed may be attributed to a number of factors not evaluated in the present study.

These factors are: First, distribution of individual storms from watershed to watershed. The 21 storms used in the analysis were assumed to be of equal intensity and volume on each watershed. Second, differences in drainage patterns of the individual watersheds. For example, watersheds D and E are short, steep, oval shaped drainages, in contrast to watersheds C and F which are long and narrow; these differences account for different channel absorption characteristics. Third, vegetative composition varied from watershed to watershed in both the overstory and understory, giving rise to differences in interception and surface detention rates. Fourth, distribution of soils with and without a clay layer, on the individual watersheds. For example, the runoff behavior of watershed A has been attributed to the relatively large area of soils with a clay layer, while the different behavior, under the same storm, of watershed E has been attributed to the relatively large area of soils without a clay layer. And lastly, when the small amounts of storm runoff were expressed in inches, the resulting number was so small that analysis was difficult. This was particularly true in relating large amounts of rainfall excess to fractions of an inch of runoff. This may indicate that certain of measured runoff values were from storms which did not completely cover the individual watersheds.

To overcome the variation of runoff experienced on the watersheds the data from the six watersheds were pooled into 21 storm events and an average regression equation was obtained, i.e., an equation to estimate the average surface runoff from the watersheds. This equation reduced, considerably, the variation of estimated runoff and hence reduced the standard error of estimate, which in the initial regression was larger than the mean actual runoff. This method resulted in smoothing out the variation in storm runoff from the watersheds and a regression between rainfall excess and actual runoff accounted for 40 per cent of the variation.

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[1]By squaring the correlation coefficient (0.4170) a relative figure of per cent variation accounted for in the regression is obtained.

The runoff estimates obtained through the use of the average regression equation were tested against the actual runoff values measured on watersheds B and D for seven storm events during 1948 to 1954 and were found to be of similar magnitude. The regression equation resulting from the pooled data, although requiring further testing elsewhere, best expresses the general relation between rainfall excess estimates and actual runoff.

The use of additional variables, i.e., total rainfall of each storm, rainfall for the first 30 minutes of each storm, and antecedent rainfall (7 days prior to the storm event), in a multiple regression with estimated rainfall excess and actual runoff did not strengthen the method of estimating surface runoff. Antecedent rainfall proved to have a non-significant relation with actual runoff, which is in agreement with a report by Musgrave. This may be attributed to the fact that large storms of 1 inch or more are infrequent and that total antecedent precipitation is often made up of storms of 0.25 inch or less.

The factors of total rainfall and rainfall for the first 30 minutes of storm proved to be highly correlated with estimated rainfall excess, thus destroying the effectiveness of multiple regression, which requires the independence of variables.

To obtain more accurate estimates of surface runoff on the individual watersheds the study has indicated the necessity of an individual regression equation for each watershed. This was pointed out by the low standard error of estimate resulting from a regression equation derived for watershed A. It is apparent from the analysis of watershed A that individual watershed relations between estimated rainfall excess and actual runoff would be useful in analyzing the runoff behavior of the six watersheds individually. Such an analysis would limit the applicability of the results of this study appreciably and would only contribute to an understanding of runoff behavior of the individual watersheds concerned. With the small values of recorded runoff, it was considered that such an analysis would have little justification or meaning.

Southeastern Forest Experiment Station
QUARTERLY PROGRESS REPORT
April - June 1955
DIVISION OF WATERSHED MANAGEMENT RESEARCH

SUMMARY

Page

Coweeta Hydrologic Laboratory
- Quantities of Erosion on Mountain Farm ---------- H-1
- Logging Methods ---------- H-1
- Soil Moisture Relations - Porters Stony Loam ---------- H-5
- Soil Characteristics of Watershed No. 17 ---------- H-6
- Analysis of Annual Minimum Instantaneous Discharges ---------- H-8
- Hydrologic Notes ---------- H-10
- Cooperation ---------- H-11
- Visitors ---------- H-12
- Publications ---------- H-12

Piedmont Research Center
- Climatic Summary ---------- H-13
- Eroded Watershed ---------- H-13

Southeastern Forest Experiment Station
QUARTERLY PROGRESS REPORT
April - June 1955
DIVISION OF WATERSHED MANAGEMENT RESEARCH

COWEETA HYDROLOGIC LABORATORY

Quantities of Erosion on Mountain Farm

In the April-June 1954 report a chart of the soil losses on Watershed No. 3 was presented. The excessive erosion in the 13th year is very striking. In the first quarter of 1954 seven storms produced 200 tons of sediment. At this stage of rapid deterioration it was decided to terminate the use of the area for grazing, and a cover of lespedeza, oats and sericea was sowed in April. The area was rapidly revegetated leaving practically no bare spots. The effect of this treatment on soil losses is indicated in Fig. 1, showing the greatly reduced losses in the 14th year.

Logging Methods

Watershed No. 41 (Fig. 2),a high elevation watershed, was selected as an area for integrated timber and watershed management. Timber was marked and the proposed haul roads located in December 1954. The timber sale contract was let to the Gordon Lumber Company of Asheville, N. C., in April and logging began immediately. Approximately 135 M bd. ft. of the 172 M bd. ft. total marked has been cut to date. Termination date of the sale is September 20, 1955.

Approximately 1.44 miles of secondary haul roads were laid out on the contour (see map) with very short steeper pitches. Long dips were constructed to prevent the rapid flow of water down the road. Culverts were put in at all permanent flowing streams.

Logging is done uphill to the road with an A-frame power skidder. This provides greater control of the log; therefore, it can be skidded away from the stream, eliminating skid trails in the permanent stream channels. This also eliminates concentrated skidding, which may disturb the sub-soils and cause erosion. The "Western snub" is applied to the logs to help keep the logs from digging in the sub-soil. All logs were truck loaded on the road.

Maintenance was performed daily to keep the drainage structures open and the roadbed smooth. Use of the roads was not permitted for a 24-hour period after a 1.5 inch or larger rain, also during prolonged wet conditions when such use would cause deep rutting and result in erosion through accumulation of water in the ruts.

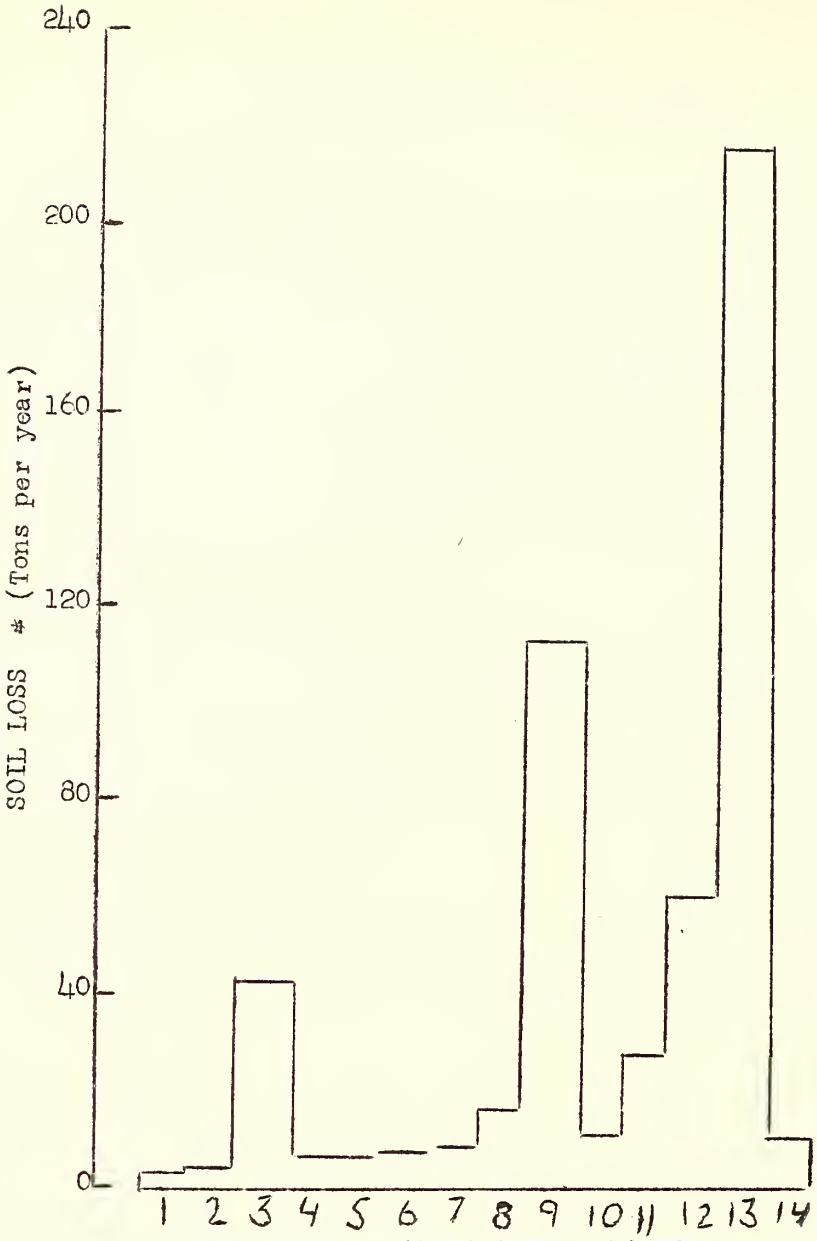

Fig 1 - Average yearly soil loss from a mountain farm watershed during the first fourteen years after clearing from a forest

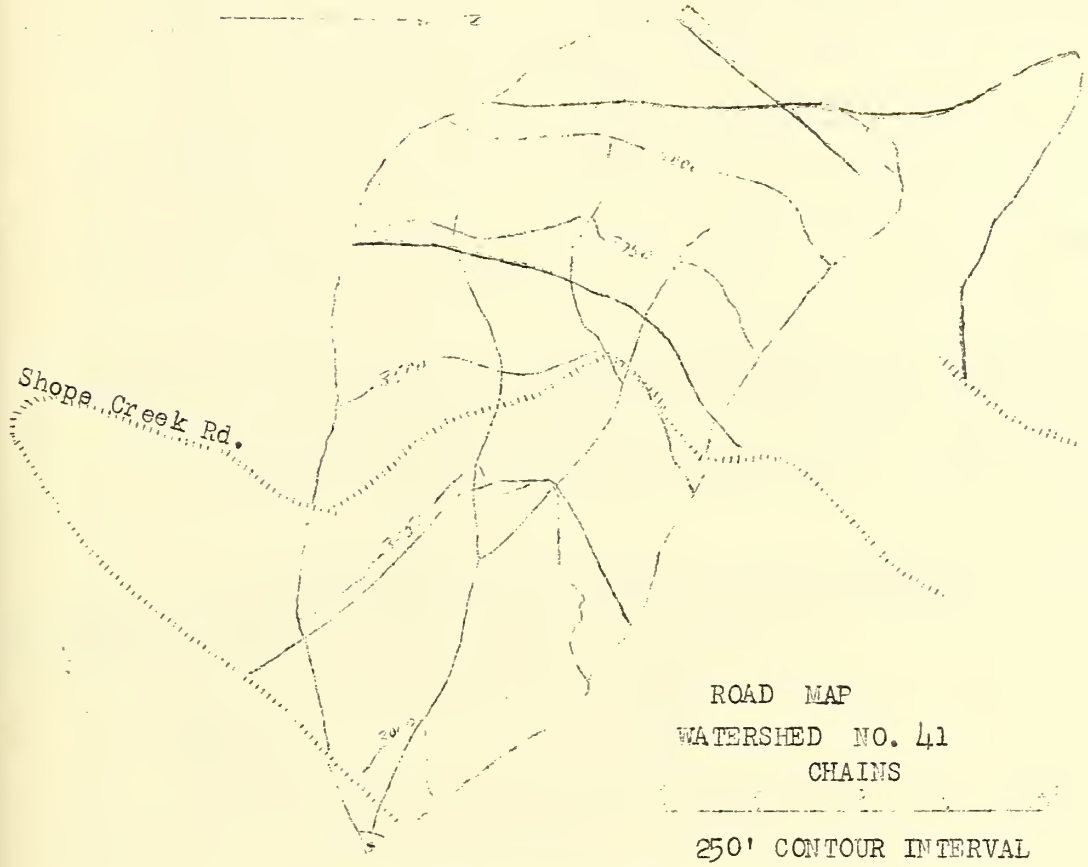

Fig. 2.--Watershed No. 41.

After a given operation was completed the road was immediately smoothed and water diversions constructed where needed. The road was then seeded to oats and ryegrass.

So far the operation has not notably increased turbidities in the permanent flowing stream as shown in the table below:

Table 1.--Average Turbidity, Watersheds No. 34 and No. 41

1955 Month	*No. of samples	Forested control No. 34 (ppm)	Logged watershed No.41 (ppm)
April	9	2.2	1.9
May	23	2.7	4.5
June	22	2.4	3.4
Average		2.4	3.3
Maximum		18.7	22.3

*1 sample per day

The values include both storm and non-storm conditions. The turbidities on W.S. No. 41 are still within the standard for excellent quality water. On an uncontrolled logging operation (Watershed No. 10) the following summary data show that turbidities were markedly increased. Of course, the climatic factors may not be exactly comparable for 1946 and 1955.

Table 2.--Average turbidity, Watersheds No. 10 and No. 34

Date	Forested Control No. 34	Logged Watershed No.10
	ppm	ppm
6/10 - 9/20/1946	4.3	93.7
Maximum	80.0	3500.0

Soil Moisture Relations - Porters Stony Loam

In an attempt to characterize the moisture relations of the Porters Stony Loam soil type present on Coweeta watersheds 1 and 2 both undisturbed and disturbed soil samples were collected from three soil depths. These samples were then subjected to tensions ranging from 0-16 atmospheres pressure. Values under one atmosphere were obtained from the undisturbed soil samples with the tension table apparaturs, while values from one to sixteen atmospheres were obtained from the disturbed soil samples with the pressure plate apparatus as designed by R. A. Richards. No direct comparison between the methods is intended.

Table 3.--Water removed from Porter's Stony Loam soil type at various soil moisture tensions for three soil depths.
(In inches)

Soil Depth	Soil moisture tension								
	Saturated	20cm	60 cm	1 At.	2 At.	4 At.	8 At.	16 At.	Water remaining
0-6"	3.94	1.04	0.90	0.80	0.19	0.16	0.15	0.12	0.58
2-3'	7.22	1.01	0.92	2.00	0.34	0.38	0.42	0.43	1.72
4-5'	6.97	1.36	1.11	1.59	0.33	0.33	0.36	0.36	1.53

The inches of water removed from the undisturbed soil samples at the 20 and 60 cm tensions indicate that a much higher proportion of large pore space exists in the 0-6" soil layer as compared with the 2-3' and 4-5' layers. However, the 2-3 and 4-5 foot soil depths seems to be represented with approximately the same proportion of pores drained at the 20 and 60 cm tensions.

For tension of one to 16 atmospheres, little difference is present between the depths in the water removed. The organic matter present in the 0-6" soil layer accounts for the ability of this layer to retain the same amount of moisture as the 2-3 and 4-5 foot depths, which are located in the B horizon. This soil horizon has a greater amount of clay present, and as a result should have a higher water holding capacity. It is evident that the clay fraction makes up a small percentage of the total primary particles present. If the clay fraction were large, the B-horizon would have retained a greater amount of water in comparison with the A horizon or o-6" soil layer.

If the 16 atmosphere tension is arbitrarily choosen as a point at which water ceases to become available to plants, and the 60 mm tension is designated as the tension which removes all gravitational water, then the total water available to plants is 1.42 inches for the 0-6" layer, 3.57 inches and 2.97 inches for the 2-3' and 4-5' soil depths.

Since the Porter's Stony Loam soil has a high sand content, a large percent of the available water is removed at the lower tensions. Consequently, in order to better define the moisture relations, more values will be obtained between the 60 cm and one atmosphere tensions.

Soil Characteristics of Watershed No. 17

In the Oct.-Dec. 1953 Progress Report volume weights and porosity of the soils on Watershed No. 17 were shown. In making further comparisons with the soils on the forested control Watershed No. 18, Freeland has found that the cutting has evidently produced only minor alterations to date in most of the pedological characteristics of the soils on No. 17. One such characteristic which appears to have been influenced by the treatment is the structure of the surface layer of soil. Laboratory aggregate analysis results by the Yoder wet-sieve method with corrections for primary particles are given in Table 4.

Evidently the percent of aggregates in the largest size class - larger than 4mm- has been reduced by the treatment. This applies to the 0-3" and 3-6" soil layers only. In the other size classes the effect is not evident. In fact, soil structure on the two watersheds is remarkably alike after 12 years of treatment and there is no evidence that this minor change in structure has affected the hydrologic characteristics of the soil.

Table 4.--Summary of aggregate analysis

SOIL SITE I [1/]

Watershed and depth of soil layer (Inches from surface):	Proportion of aggregates in each size class in percent Larger than: 4 mm	2-4mm	1-2 mm	0.5-1mm	0.25-0.5mm	.105-.25mm
Watershed 18						
0-3	24.51	21.17	14.29	10.59	2.98	1.27
3-6	28.07	20.43	13.26	9.98	3.64	0.97
12-15	7.95	13.92	11.23	14.11	11.71	8.61
30-33	4.05	6.50	9.53	14.92	13.33	7.76
Watershed 17						
0-3	6.94	15.90	12.95	16.74	8.94	1.66
3-6	10.70	19.92	13.66	12.53	8.21	2.63
12-15	5.80	11.48	13.43	18.35	12.44	2.61
30-33	7.57	10.74	10.85	15.67	12.99	4.65
SOIL SITE II						
Watershed 18						
0-3	9.72	12.79	11.93	11.91	7.28	4.93
3-6	18.33	16.20	13.25	10.99	5.07	4.47
12-15	5.79	15.52	11.86	13.71	10.23	7.39
30-33	10.36	9.58	9.97	11.48	9.79	5.85
Watershed 17						
0-3	7.41	15.06	12.41	13.87	7.95	5.09
3-6	10.21	14.53	9.96	12.70	9.17	6.93
12-15	9.77	12.37	10.87	12.31	11.44	5.99
30-33	2.93	7.50	9.58	14.35	12.51	7.49
SOIL SITE III						
Watershed 18						
0-3	15.65	14.64	10.92	9.89	5.62	6.97
3-6	11.79	14.07	12.36	12.59	8.76	7.38
12-15	12.19	14.54	10.17	11.77	10.84	8.03
30-33	13.43	12.95	10.44	12.07	10.09	7.88
Watershed 17						
0-3	6.39	10.88	9.70	13.15	11.17	3.15
3-6	11.83	14.20	11.69	12.30	8.05	4.06
12-15	5.45	13.29	10.68	11.29	9.61	6.15
30-33	8.15	8.43	10.44	13.58	9.97	3.43

1/ Soil Site Classes I, II, and III correspond to cove, middle and lower slope, and upper slope-ridge sites, respectively.

Analysis of Annual Minimum Instantaneous Discharges

In the Jan.-Mar. 1954 Progress Report it was shown that annual floods from small forested headwater areas in the Southern Appalachians may be analyzed using the extreme value theory of Gumbel. Since the theory assumes no upper (or lower) limit it could not be applied to annual minimum flows which are limited by zero or a small positive value. Gumbel 1/ has since developed a statistical theory of droughts (annual minimum flows) which overcomes this obstacle and appears to provide a satisfactory fit to such data.

Nineteen years of data from Watershed No. 14 are shown in Table 5. Extremal probability paper can be used, as in the case with floods, but the common logarithm of the drought is plotted against the frequency m / N+1.

If the lower limit of droughts is zero the data should plot as a straight line on logarithmic extremal probability paper. Obviously, this assumption will not hold true for most large rivers, and the result is that we get a curve which is asymptotic to a horizontal line above the zero axis. In Figure 3 we find that this condition also obtains for the Coweeta streams. For most small streams, however, in a lower rainfall belt, the zero lower limit would probably apply.

According to the analysis, the asymptotic lower limit, e, is 0.355 csm and the derived relationship is

$$\log (x-.35539) = -0.27953-.35091y$$

where x is the minimum flow and y is the reduced variate introduced by Gumbel (see Fig. 1). For the 100-year drought, y = +4.6, we have x = 0.361 csm or .086 cfs. Incidentally, the 100-yr. flood was estimated at 135 csm so that the ratio of extreme flows is approximately 400 to 1. The 100-yr drought does not differ greatly from the 19-year extreme drought of 0.384 csm. This is not unexpected due to the fact that groundwater depletion proceeds very slowly in this range of flows and is little affected by extended periods without rain which might occur in the 100-year interval. The analysis leads, therefore, to results which are in good agreement with observed streamflow characteristics.

The definition of droughts as the annual minima of discharges is quite unfortunate. The common meaning has to do with dry spells as they affect growth of plants, and the two are not always closely related. For example, as noted earlier a small reduction in the minimum discharge near the lower limit would probably correspond to a very large increase in drought severity affecting plant growth.

In regard to the earlier flood frequency analysis some comments have been received advocating the use of the logarithmic-normal distribution of flood probabilities as being much simpler. In dealing with extreme values, however, it is more logical and appropriate to use this "a priori" information and deal with extreme value distributions. The log-normal distribution actually fails in a great many cases and is not reliable for extrapolation.

1/ Gumbel, E. J. Statistical theory of droughts. Proceedings Am. Soc. of Civil Eng. Vol. 80. Separate No. 439. May 1954. 20pp.

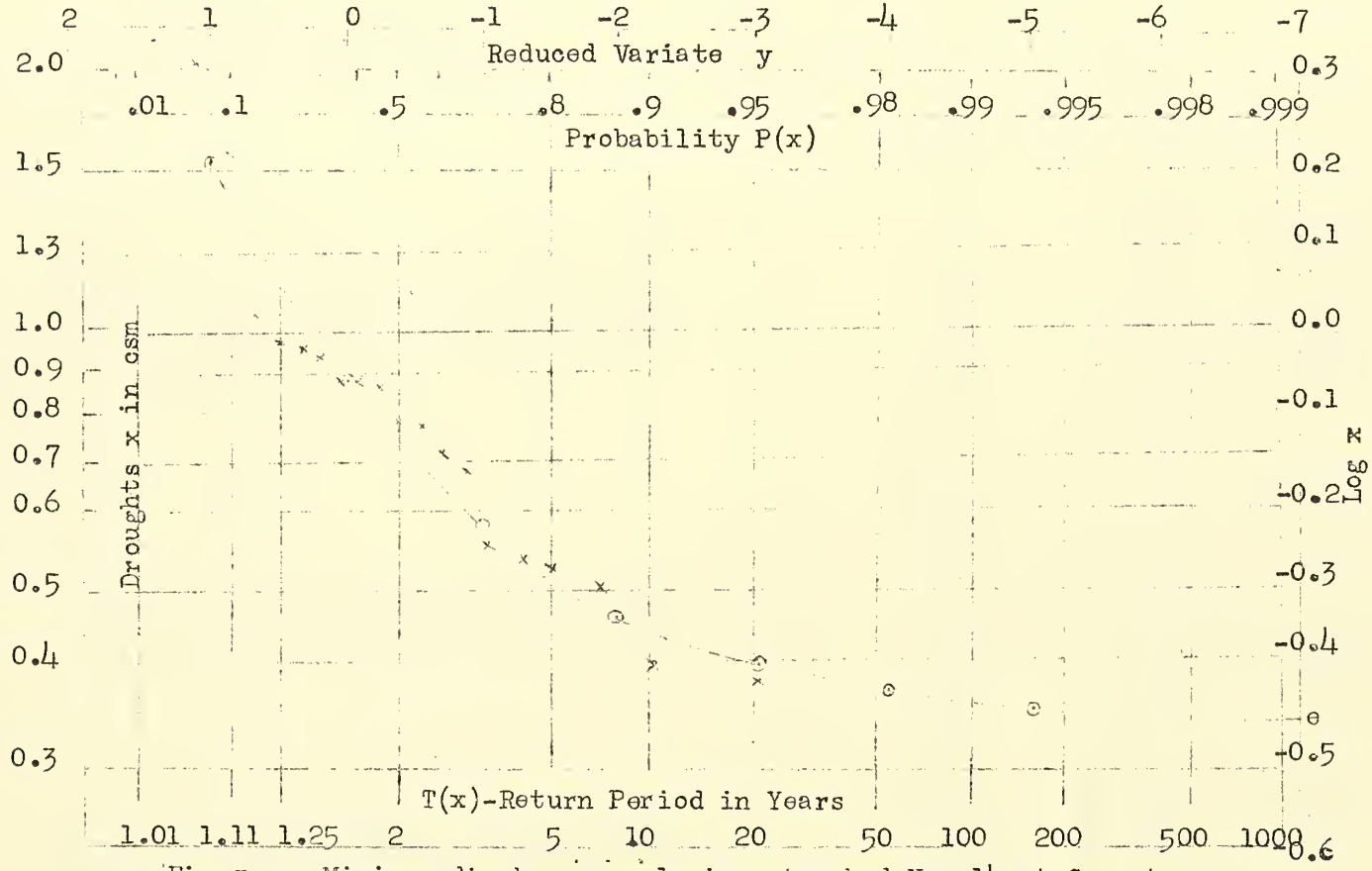

Fig. 3 - Minimum discharge analysis watershed No. 14 at Coweeta

Table 5.--Minimum annual discharges
Watershed 14

Year	Minimum discharge	Logarithm of minimum discharge	Frequency	Return period
	C sm	Csm		Years
1949	2.023	0.30600	0.05	1.053
1938	1.589	0.20112	0.10	1.111
1937	1.041	0.01745	0.15	1.176
1936	0.976	-0.01055	0.20	1.250
1943	0.960	-0.01773	0.25	1.333
1942	0.936	-0.02872	0.30	1.429
1948	0.891	-0.05012	0.35	1.538
1939	0.883	-0.05404	0.40	1.667
1940	0.868	-0.06148	0.45	1.818
1946	0.782	-0.10679	0.50	2.000
1951	0.774	-0.11126	0.55	2.222
1950	0.727	-0.13847	0.60	2.500
1944	0.688	-0.16241	0.65	2.857
1947	0.565	-0.24795	0.70	3.333
1952	0.542	-0.26605	0.75	4.000
1945	0.526	-0.27901	0.80	5.000
1941	0.509	-0.29328	0.85	6.667
1953	0.407	-0.39041	0.90	10.000
1954	0.384	-0.41567	0.95	20.000
Mean	0.846	-0.111	---	----

Hydrologic Notes

Air temperatures for June were substantially below normal due mainly to the unusual number of rainy days. The average maximum was the same as that for May whereas the normals show a 6° difference.

Table 6.--Climatic summary of air temperatures and evaporation

Month	Average		Maximum		Minimum		Evaporation	
	1955 of	Dev. from normal of:	1955	Dev. from normal of:	1955 of	Dev. from normal of:	1955 in	Dev. from normal in.
April	58.0	+2.2	73.0	+4.4	43.0	+2.0	4.15	+.39
May	63.0	+1.9	77.0	+1.2	49.0	+2.4	4.85	+.75
June	65.5	-5.3	77.0	-5.1	50.0	-5.6	3.89	-.14
Aver.	61.5	-1.2	75.7	+0.5	47.3	-1.2	4.30	+1.00

Precipitation in April and May was very heavy, the latter being twice the normal amount. The excess for the water year beginning Nov. 1 amounts to 9 inches and is due to the heavy rainfall in this quarter. Although June totaled only 4 inches, there were 15 days with rain in this month. This was mainly thunderstorm activity which occurred regularly in the afternoon.

Table 7.--Precipitation summary

Month	1955	Dev. from normal
	Inches	Inches
April	8.36	+2.44
May	11.01	+6.60
June	4.24	- .37
Quarterly total	23.61	+8.67
Water yr. to 6/30	58.28	+9.39
Cal. yr. to 6/30	43.22	+6.20

Cooperation

Universities

There were 3 thesis projects completed this quarter. The final draft on a 4th thesis was received and is currently being reviewed.

Jacob L. Kovner received his Ph.D June 6th at the New York State College of Forestry. His thesis utilized data from Watershed No. 13. Current plans are to edit the thesis for submission to Forest Science.

Kenneth Pitcher received his Master of Science degree at the North Carolina State College. His thesis "The Influence of Cove Site Vegetation on Streamflow and Soil Moisture in the Southern Appalachian" utilized data from Watershed No. 1. This was a cooperative aid project with the N. C. State School of Forestry. Plans are to condense the thesis for an article in Soil Science of America.

Mohammad Said Katana of Iraq received a Master of Forestry at North Carolina State College on "Some Comparisons of Precipitation, Streamflow, and Soil on a Denuded, a Grass-Covered, and a Forested Watershed in the Copper Basin of Tennessee." The Station does not plan to publish on this because of some limitations in the study.

Assistance has been requested by the Department of Forestry, University of Missouri on a cooperative watershed management research project in the Southeast Missouri Ozarks. This project "Effect of forest cover on soil and water resources" is proposed as a joint undertaking by the University of Missouri, U. S. Forest Service, Army Corps of Engineers, and U. S. Geological Survey.

Preliminary arrangements have been made with the U. of Minnesota School of Forestry to have Professor Donald Duncan spend an extended period at Coweeta during the fall months. Professor Duncan plans to study watershed management research and obtain data that will help in the courses he is giving at the University.

The School of Natural Resources, University of Michigan informed us that Professor Dils has joined their staff. Also, that Professor Dils and Brater in the School of Civil Engineering will be giving courses in watershed management and hydrology. Preliminary arrangements were made this quarter for a Masters Thesis project under the new program at Michigan.

Visitors

Visitors continued coming this quarter and during this period we discussed our research program in the field to 28 groups totaling 433 individuals. The January-June 1955 total is now 40 groups and 548 people. In addition, at 4 lectures 680 individuals became familiar with the research program. For the first half of 1955 the staff at Coweeta have personally informed over 1225 people about the Forest Service Research Program at Coweeta. We appreciate the interest in watershed management but interruptions resulting from this heavy information and education program is seriously interfering with the carrying out of our primary function--that of doing research.

As part of the Southeastern Station functional inspection, Bernard Frank visited Coweeta May 16-18.

Publications

Nelson, T. C.
Chestnut Replacement in the Southern Highlands, Ecology, Vol. 36, No. 2, pp 352, 353. April 1955.

PIEDMONT RESEARCH CENTER

April - June 1955

Climatic Summary

The weather for this past quarter has been rather normal with the exception of the storm of April 24. Precipitation was above normal in April and May, but fell 2.60 inches below normal for June. We now have a cumulative deficit for the calendar year of 3.68 inches. The quarterly summary is as follows:

Quarterly Climatic Summary - Calhoun Experimental Forest

Month	Average temperatures: Max.	Min.	Mean	Highest temp.	Lowest temp.	No. of days with rain	Precip.	Evap.
	°F	°F	°F	°F	°F		Inches	Inches
April	77	49	63	87	28	10	4.31	5.34
May	84	56	70	93	40	8	3.69	6.50
June	85	56	70	95	45	5	1.20	6.53

Eroded Watershed

The stabilization of Watershed #1 (see Quarterly Report July - Sept. 1949) was started this quarter. This 15-acre watershed had about 4 acres in a barren eroded condition which contributed considerable soil to the stream below. The barren area was bulldozed, fertilized, and seeded with lespedeza and crotalaria. Pine needles and lespedeza straw were used for mulching and a number of small dams were built just below the treated area. During this coming winter, the area will be planted to loblolly pine. Comparisons before and after treatment will be made for soil loss and peak flows after the vegetation has become well established.

Storm Damage

On the afternoon of April 24, a severe thunderstorm passed over Union County bringing with it very high winds. Three weeks later we accidentally discovered the results of this storm--30 acres of windthrown timber.

The timber was mostly shortleaf pine between 60 and 80 years of age, and was located on Vance soil which has a very tight clay subsoil. Most of the trees were uprooted but many were broken off, some at the base and others at various points along the stem. The interesting feature was the shallow root systems exhibited by nearly all of the uprooted trees. Shortleaf pine generally has a fairly deep taproot extending 6 to 10 feet into the soil. A sample of 21 windthrown trees showed that on the average the tap roots did

not extend more than 2.7 feet into the soil. It was plainly discernible that the roots could not penetrate the tight clay subsoil. In many instances the roots twisted and turned back on themselves developing into a variety of S-shaped formations.

The down-timber was marked and tallied by the Ranger and is now being salvaged. Following is a summary of the volume of timber involved:

No. of trees	Volume
382	33.3 MBM Pine sawtimber
8	1.0 MBM Hardwood sawtimber
5	0.2 MBM Cedar sawtimber
95	5.0 cords Pine pulpwood

Southeastern Forest Experiment Station
QUARTERLY PROGRESS REPORT
July - September 1955
DIVISION OF WATERSHED MANAGEMENT RESEARCH

COWEETA HYDROLOGIC LABORATORY

Influence of Degrading and Restoration Practices on Storm Peak Flows from Watershed #3

The land use watersheds now subjected to a better form of management are providing new data for evaluating the rapidity in which a degraded watershed recovers and watershed protection properties approach the original undisturbed forest. Changes in streamflow, soil and vegetation under the restoration program are producing interesting information on how quickly some recover.

Coweeta Watershed 3 was gaged from 1934-1940 under a forest cover. The forest was cleared away in 1940 and the land area was maintained as a mountain farm until 1954. In April 1954 use of the area for grazing and mountain farming was terminated and a cover of oats, Korean lespedeza and lespedeza sericea was sown. In March 1955 the area treated the previous year was planted to white pine and yellow poplar.

Analysis this quarter of changes in storm peaks from summer type thunderstorms shows striking reductions the first two years after a cover crop was planted, Fig. 1. Prior to operation as a mountain farm, Watershed 3 had a maximum storm flow of 54 c.s.m. and forest control Watershed 2, 28 c.s.m. for the summer type storms. During 1952 and 1953 the cumulative effects of 12 and 13 years of degrading agriculture resulted in maximum storm flows of 865 c.s.m. on Watershed 3, while the control recorded only 17 c.s.m. Under a restoration program maximum flow on Watershed 3 was 42 c.s.m. and on Watershed 2, 6 c.s.m. the first growing season with 39 c.s.m. on the treated and 37 c.s.m. on the control during the second growing season.

Average storm flow under a forest cover on Watershed 3 was 29 c.s.m., during 1952 and 1953, 254 c.s.m., and the first two years under a cover of oats, lespedeza and tree seedlings 22 c.s.m. Control Watershed 2 storm flow averages for the same three periods were 14, 9 and 10 c.s.m. respectively.

Reduction in maximum storm flow to rates observed under the original forest during summer type thunderstorms were much faster than anticipated. Although data in Figure 1 indicate the present vegetal cover quickly reduced maximum storm flows to pretreatment values, one should not apply this to the winter type storms. Since the restoration treatment has been underway for only one winter season there is an insufficient number of these storms available to date for analysis.

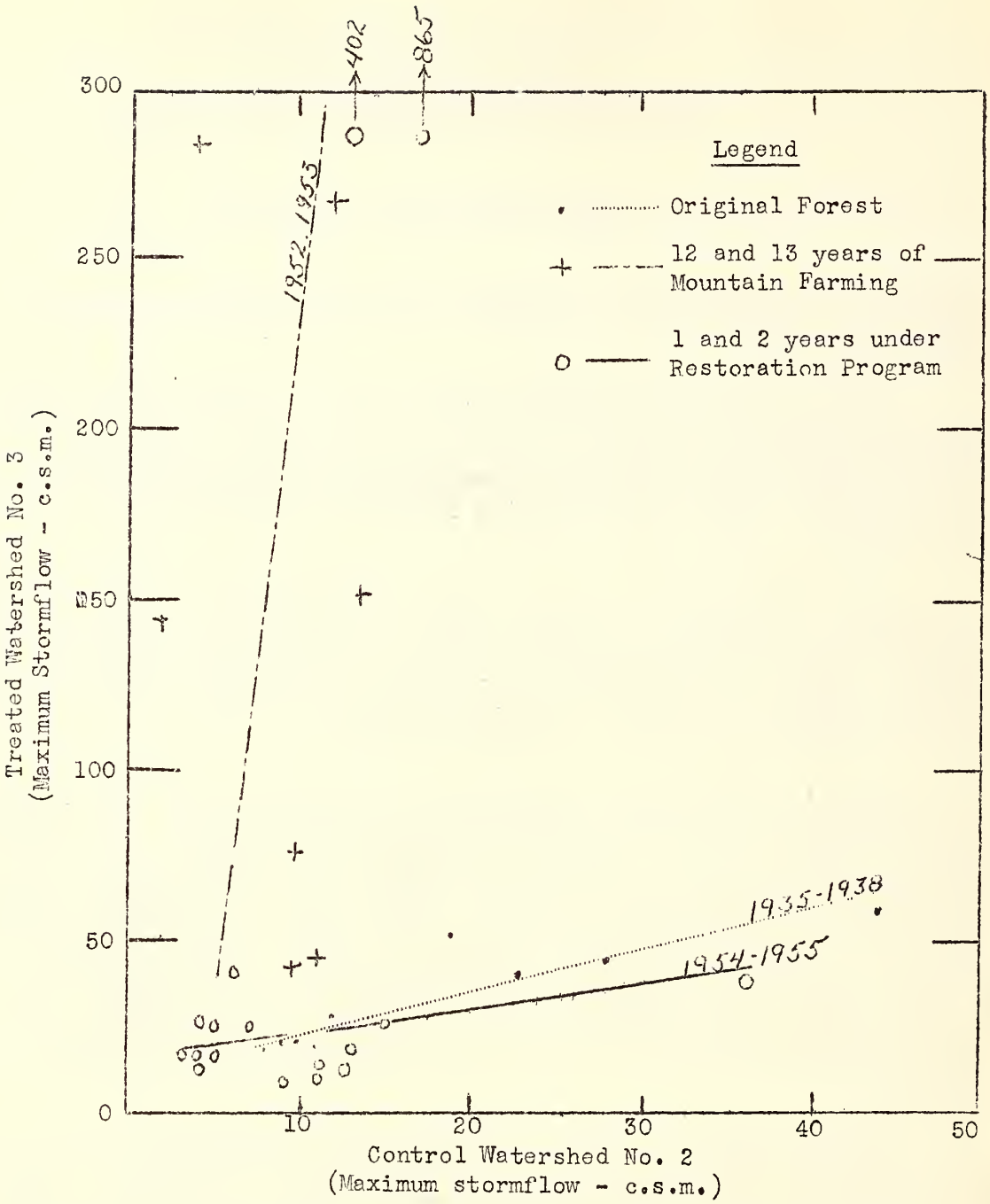

Fig. 1 Maximum Stormflow from summer type thunderstorms under original forest cover and degrading and restoration land use practices on Watershed No. 3

Comparative Water Yields Under Two Systems of Management

Maximum economic returns under a system simulating that on National Forest Lands, Watershed 41.--The first improvement cut for placing the forest stand on this area under management was completed September 20. The design for harvesting forest products was a series of contour secondary haul roads leading off Shope Creek Road, that is the climbing road. Logging was done uphill to a haul road with an A-frame power skidder. All logs were loaded into trucks by the power skidder. Maintenance was performed daily on the haul road being used in order to keep structures open and the roadbed smooth. After the logging was completed along a section of haul road it was immediately smoothed, deeper water diversions constructed and seeded to oats, rye grass or rye. Thus at any one time there was a minimum of exposed mineral soil not protected by some grass cover. Even though rainfall was heavy and 7 inches above normal during the period of active logging it did not damage the high quality water resource of the watershed. Table 1 gives a comparison in water quality from samples collected daily for a treated watershed during a logging operation with an undisturbed control watershed.

Table 1.--Stream turbidities and precipitation during a logging operation for a treated and control watershed.

Month	Precipitation	Logged Watershed: Average	Logged Watershed: Maximum	Control Watershed: Average	Control Watershed: Maximum
	Inches	p.p.m.	p.p.m.	p.p.m.	p.p.m.
April	8.64	1.9	5.3	2.2	5.0
May	11.52	4.5	22.3 1/	2.7	18.7 1/
June	6.24	3.4	5.6	2.4	5.0
July	10.02	5.3	62.0 1/	1.8	3.8
August	4.93	2.5	5.9	1.5	2.3
September	2.76	4.3	20.9 1/	4.2	8.4

1/ Only 4 samples (62, 22, 21, and 19 p.p.m.) collected during the study exceeded Public Health Standards of 11 p.p.m. A visual examination indicated the composition of the solid particles were organic and not of a mineral character.

Another point of interest to foresters near Coweeta is difference in the volume marked by tree measurement standards with volume obtained by a log scale using Scribner's Decimal C. Table 2.

Table 2.--Comparison of tree measurement and log scale volumes first improvement cut, Coweeta Watershed No. 41.

Species	Tree measurement volume marked	Log scale volume	Difference	Percent
		Bd.ft.		
Hemlock	4,651	6,800	+2,849	146
Pitch Pine	1,253	1,000	- 253	80
Black Oak	6,772	5,130	-1,642	76
Chestnut Oak	20,261	16,810	-3,451	83
Northern Red Oak	66,792	67,290	+ 398	101
Spanish Oak	10,495	5,050	-5,445	48
White Oak	15,254	13,000	-2,254	85
Yellow Poplar	23,498	27,520	+5,022	117
Red Maple	3,674	1,900	-1,774	52
Black Gum	1,563	980	- 583	63
Black Birch	3,203	1,880	-1,323	59
Buckeye	7,444	7,190	- 254	97
Black Cherry	187	170	- 17	91
Ashe	1,128	890	- 238	78
Basswood	5,619	6,904	+1,321	123
Total	171,794	162,651		

$$\frac{162,651}{171,794} = 94.68\%$$

The larger scaled volume in Yellow Poplar was due to many forked trees that produced several logs in the larger limbs. The lower scaled volume in Chestnut, Scarlet and White Oaks resulted from excessive decay in hidden defects on old growth trees cut on the upper ridges.

Optimum yields of useable water plus some supplemental timber returns Watershed No. 40.--The first improvement cut started this quarter. It uses a similar road design, with logging uphill by a power skidder, and maintenance standards similar to Watershed 41. All water samples that have been collected from this watershed are within the standards for excellent quality water.

Soil Moisture Deficits Created by the Cove Site Woody Vegetation

In March, 1954, the cove site woody vegetation on Coweeta watershed No. 1 was deadened. Thus, the transpiration draft upon soil moisture by this forest type was eliminated. In order to determine the amount of water which remained stored in the soil as a result of this treatment, the gravimetric method of measuring soil moisture was employed. Soil moisture samples were collected by depth intervals from cove sites in the treated watershed and from comparable cove sites in an adjacent control watershed. Comparisons between the control and treated watersheds give an estimate of the influence of the cove site woody vegetation upon soil moisture.

The soil moisture deficit as reported here is the difference in inches between soil moisture at field capacity and observed soil moisture at time of sampling. Total water readily available for evapotranspiration is the difference in inches between field capacity and wilting point. In 1954, the soil moisture deficit under the treated woody vegetation was 1.54 inches of water which is 11.5 percent of the total water available for evapotranspiration. On the control watershed, under the undisturbed cove vegetation, a soil moisture deficit of 7.11 inches was measured, which is 51.2 percent of the total water readily available for evapotranspiration. The difference of 5.57 inches is the net result of treating the cove vegetation.

In 1955, the soil moisture deficit under the treated vegetation was 2.18 inches or 15.4 percent of the total readily available water, while the soil moisture deficit for the control cove sites was 4.32 inches or 30.4 percent of the total readily available water. For the 1955 growing season the net influence of treating the cove vegetation was 2.04 inches. (Tables 3 and 4). The decrease in the soil moisture deficit in the 1955 growing season was due to the increased precipitation. During the 1954 growing season 24.18 inches of rainfall was measured on the watershed, while during the 1955 growing season the watershed received 37.23 inches, an increase of 13.05 inches over 1954.

The largest soil moisture deficits were created in the first two feet of soil under the treated cove vegetation. This shows that a large portion of the moisture was withdrawn by the shallow rooted herbaceous vegetation and by the process of evaporation. On the control site, however, the moisture seems to have been withdrawn more uniformly from the soil profile, with comparable deficits at all depths down to 6 feet. The deeper rooting characteristics of the forest vegetation is responsible for this phenomenon.

Table 3.--Soil moisture values by depth intervals for the treated and untreated cove site vegetation (average of four stations in inches of water)

SEPTEMBER 1954

Depth	Watershed No. 1			Watershed No. 2		
	Soil moisture	Soil moisture deficit	Remaining moisture available to plants	Soil moisture	Soil moisture deficit	Remaining moisture available to plants
0-6"	1.84	0.14	0.85	1.21	0.73	0.22
6-12"	1.45	0.42	0.46	1.22	0.49	0.23
12-24"	3.07	0.49	1.79	2.73	0.91	1.45
24-36"	3.77	0.03	2.49	2.86	0.96-	1.58
36-48"	3.81	0.04	2.53	2.34	1.22	1.06
48-60"	3.32	0.17	2.11	2.27	1.23	1.06
60-72"	3.75	0.25	2.54	2.38	1.57	1.17
Total	21.01	1.54	12.77	15.01	7.11	6.77

SEPTEMBER 1955

0-6"	1.38	0.60	0.39	1.38	0.56	0.39
6-12"	1.31	0.56	0.32	1.50	0.21	0.51
12-24"	2.83	0.73	1.55	2.91	0.73	1.63
24-36"	3.74	0.06	2.46	3.30	0.52	2.02
36-48"	3.73	0.12	2.45	2.90	0.66	1.62
48-60"	3.50	0.00	2.28	2.86	0.64	1.65
60-72"	3.84	0.11	2.68	3.05	0.90	1.84
Total	20.38	2.18	12.13	17.90	4.22	9.66

Table 4.--Soil moisture constants

Depth	Watershed No. 1			Watershed No. 2		
	Field capacity	Permanent wilting point	Total water available for plant growth	Field capacity	Permanent wilting point	Total water available for plant growth
	Inches	Inches	Inches	Inches	Inches	Inches
0-6"	1.98	0.99	0.99	1.94	0.99	0.95
6-12"	1.87	0.99	0.88	1.71	0.99	0.72
12-24"	3.56	1.28	2.28	3.64	1.28	2.36
24-36"	3.80	1.28	2.52	3.82	1.28	2.54
36-48"	3.85	1.28	2.57	3.56	1.28	2.28
48-60"	3.49	1.21	2.28	3.50	1.21	2.29
60-72"	4.00	1.21	2.79	3.95	1.21	2.74
Total	22.55	8.24	14.31	22.12	8.24	13.88

Changes in Streamflow as a Coppice Forest Grows Back - Vegetation and Streamflow, Watershed No. 13

In the Oct.-Dec. 1953 Progress Report a method for estimating treatment effects with time trend was presented using data from Watershed No. 13. All the forest vegetation was cut down in the fall and winter of 1939 and allowed to grow back undisturbed in subsequent years. With the addition of several years data the analysis has been revised, introducing log t instead of t in the regression equation for time trend. With this change the increase in streamflow due to treatment no longer decrease at a uniform rate with the passing years. Since the streamflow behavior is associated with plant growth, the new relationship appears more logical, and, in fact, provides a better fit for the data.

The regression curves are shown in Figure 2 on semi-log paper. Now in the 16th year of the treatment period the estimated annual increase in discharge amounts to 4 inches. Note that 2 inches or half the increase occurs in the season of ground water replenishment, that is, January 1 - April 30. This is quite a decrease from the initial increase which amounted to 14.5 inches of discharge. Extrapolation indicates that the treatment effect will be negligible after the 35th year.

The original forest stand had an average basal area of 100 sq. ft. per acre. This was reduced to zero by cuttings but by the 14th year had been reestablished at approximately 50 sq. ft. Table 5 shows the corresponding streamflow behavior.

Table 5.--Comparison of periodic changes in annual streamflow and growth

	1st.year	14th year	At termination date, approximately 40 yrs.	Change in time interval: 1-14 yrs.	Change in time interval: 14-40 yrs.
Increase in streamflow in inches	14.97	4.50	0	10.47	4.50
Basal area in sq. ft. per acre	0	50.00	100.00	50.00	50.00

Thus for the first 14 years the average rate of decrease per year would be 0.21 inches of discharge per sq. ft. of basal area per acre while from the 14th year until the termination date, which may be assumed to be in the neighborhood of 40 years, the rate is .09 inches per sq. ft. of basal area per acre. Figure 3 illustrates the periodic rates of change. Of course these average periodic rates are subject to variation within each of the selected periods.

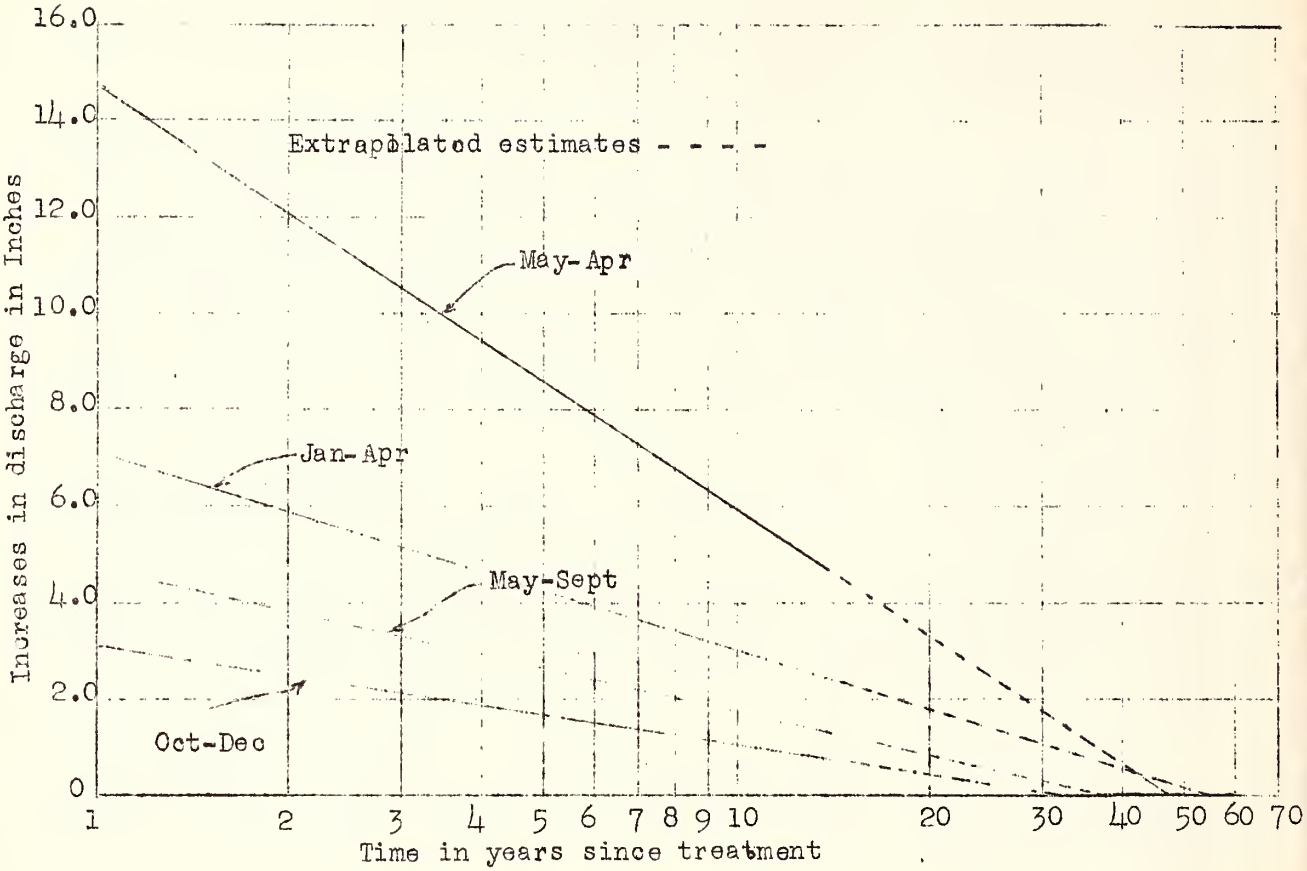

Fig. 2
Estimated increases in discharge for Watershed No 13 - by season and year

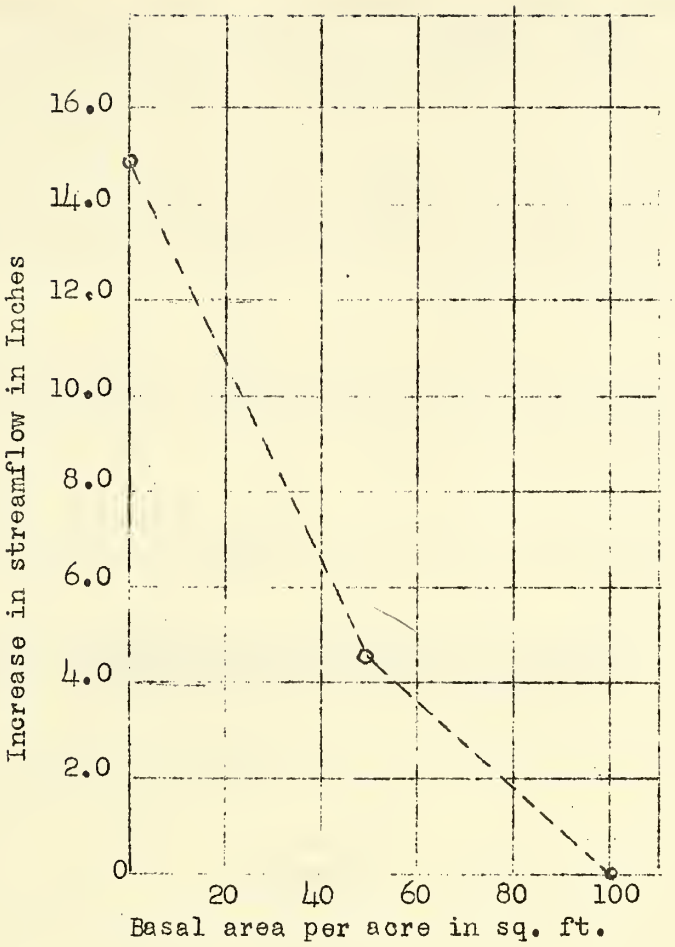

Fig. 3 Periodic Relationship
Incr. in annual streamflow vs Basal Area per acre

Changes in Streamflow Following Cutting of an Ericaceous Understory

A dense understory of Kalmia latifolia and Rhododendron Maxima is frequently associated with mountain hardwood stands. This understory is often 10 to 20 feet tall and is made up of stems that will sometimes reach a diameter of 9 inches at breast height. The foliage is evergreen, and it seems likely that these plants intercept and transpire considerable quantities of water. The assumption is made, therefore, that a hardwood forest with an extensive understory of these species will use more water than a similar stand free of such cover.

In order to test this hypothesis all the ericaceous understory on Watershed No. 19 was cut down during January and February 1949. This is a 70 acre watershed with a mean elevation of 3100 feet and supported a dense understory on 90 percent of the area.

Table 6 shows annual discharge on the treated and control watersheds for the before and treatment periods. The hydrologic year from May 1-April 30 is used.

Table 6.--Discharge by years for Watersheds No. 21 and No. 19 for the before and after treatment periods

Year May 1 - April 30	Control Watershed No. 21	Treated Watershed No. 19
Before treatment	Inches	Inches
1941-42	42.58	38.52
1942-43	60.42	55.44
1943-44	58.15	54.24
1944-45	42.13	39.28
1945-46	60.88	55.43
1946-47	46.92	44.02
1947-48	54.03	49.49
Average	52.159	48.060
After treatment		
1949-50	75.47	73.14
1950-51	50.86	49.28
1951-52	63.94	61.34
1952-53	44.08	41.52
1953-54	48.14	45.87
1954-55	41.67	39.18
Average	54.026	51.722

The analysis of covariance shows that the two periods do not have a common regression coefficient of discharge, and we cannot proceed with this analysis to test for the average increase in streamflow due to treatment. We proceed, therefore, using the regression for the years 1942-48, which is given by

$$y = 0.804 + .9060x \qquad (1)$$

where x = annual discharge on Watershed No. 21 and y = annual discharge on Watershed No. 19. The coefficient of correlation R=0.997 is very close to unity. The standard error of estimate is 0.6729 inch.

Substituting the average value of X=54.026 inches for the years 1950-55 in (1) we get an estimate of average Y=49.752 inches. The difference between this value and the observed average of 51.722 inches is equal to 1.970 inches which is significant at the one percent confidence level. The confidence limits are .44 to 3.50 inches.

The treatment has evidently resulted in an average increase of 2.0 inches in the annual discharge for the six-year period. This is only 4 percent of the estimated average discharge. The average annual losses to the atmosphere amounted to 30 inches before treatment, so that there has been a 7 percent reduction in this loss component of the water balance.

On the whole it would appear that the water balances of hardwood-forested watersheds with and without a heavy understory of ericaceous material are not greatly different.

The difference in the regression coefficients leads us to compute the difference between observed and estimated discharge on Watershed No. 19 for the individual years. These are shown in the table below together with the annual precipitation on Watershed No. 19 and a time variable.

Table 7.--Estimated increases in discharge with precipitation and time by years for Watershed No. 19

Year	Annual precipitation	Year Since treatment	Estimated increase in discharge
	Inches		Inches
1949-50	92.94	1	3.96
1950-51	76.88	2	2.40
1951-52	87.01	3	2.61
1952-53	70.70	4	0.78
1953-54	79.55	5	1.45
1954-55	68.94	6	0.62
Average	79.337	3.5	1.97

The tabular data suggest that the estimated increases are dependent on the precipitation and time variables. The derived multiple regression is given by

$$\Delta Y = -3.330 + .0807X_p - .3150X_t \qquad (2)$$

where ΔY = estimated increase in discharge
X_p = annual precipitation on Watershed No. 19
X_t = time in years since treatment

The multiple correlation coefficient R=0.9699 is highly significant. The standard error of estimate is 0.287 inch. The regression coefficient of X_p is significant at the 5 percent level while the regression coefficient of X_t is significant at the 6 percent level and has been retained in (2) above. More years of data are required before the treatment effect with time can be better ascertained. Using an average annual precipitation of 80 inches, equation (2) suggests that the effect on streamflow from cutting the understory will be negligible by the end of the 10th year. It is quite logical to expect a change in the water balance with time since sprout growth has occurred on the area in addition to replacement of cut material by other species.

It is a little more difficult to interpret the increase in discharge with precipitation. The phenomenon of interception is most closely connected with differences in precipitation for the range experienced here. Since the understory is evergreen, the removal of same would make quite a difference in the nature of the stand canopy during the dormant season. When the discharge data are analyzed separately by growing and dormant seasons, we find that the regression coefficient of precipitation, as in (2) above, is significant for the dormant season but nonsignificant for the growing season.

Hydrologic Notes

Air temperatures did not show any marked deviations from normal. Generally the eastern half of the United States experienced unusually hot weather this quarter. The maximum summer temperature recorded here was 91° F. on August 21. On two other days, July 26 and 27, the temperature reached 90°F. Otherwise the daily maximums were below this figure. The area is not a very good market for the manufacturers of air conditioning equipment.

Normally pan evaporation in July exceeds that in August but the reverse was true this quarter. There were 20 days with rain in July compared with half that number, or 10 days in August, which pretty well accounts for the difference.

Table 8.--Climatic summary of air temperatures and evaporation

Month	Average		Maximum		Minimum		Evaporation	
	1955 of	Dev. from normal of:	1955	Dev. from normal of:	1955 of	Dev. from normal of:	1955 in	Dev. from normal in.
July	72.0	+0.9	83.5	+0.1	60.4	+1.7	3.62	-0.54
August	72.6	+2.0	85.0	+2.1	60.2	+2.0	4.09	+0.33
Sept.	67.4	+2.3	80.4	+1.6	54.4	+3.0	3.30	+0.10
Average	70.7	+1.7	83.0	+1.3	58.3	+2.2	3.68	-0.04

Precipitation for the quarter was about normal. September showed a marked decrease and no rain fell during the first 24 days of the month. This was somewhat of a relief after the high frequency of days with rain which characterized the previous months. The slight deficiency for the quarter had little effect on the accumulated excesses for the water and calendar years. The water year which ends October 31 will undoubtedly show an excess amounting to about 8.0 inches.

Table 9.--Precipitation summary

Month	1955	Dev. from normal
	Inches	Inches
July	8.29	+1.78
August	5.37	- .37
September	1.60	-2.71
Quarterly total	15.26	-1.30
Water yr. to 9/30	73.54	+7.78
Cal. yr. to 9/30	58.48	+5.00

Streamflow

In the table below minimum flows for the quarter are shown for 1954 and 1955.

Table 10.--Minimum instantaneous flows

Watershed No.	Mean elevation	Discharge	
		1954	1955
	Feet	c.s.m.	c.s.m.
2	2827	.102	.407
22	3435	.375	.647
27	4155	.218	.775
37	4345	.381	.872

The minimum flows in 1954 were the lowest on record as noted in the Progress report for that year. With the sustained precipitation this year, streamflow has been maintained at normal levels, which are 2-3 times larger than the flows of 1954.

Cooperation

Universities:

Geoffrey Greene completed his Master's Thesis at the University of California. He utilized data from Watershed No. 3 for his thesis.

Glenn W. Smalley submitted the first draft of his Master's thesis for Michigan State College on: Some Criteria for Determining Unit Area Control in Watershed Management on Municipal and Industrial Watersheds in the Southern Appalachian Mountains.

Little Tennessee River Watershed Association

Upon request from officers of this Association a draft was prepared in Applying for Assistance in Planning and Carrying out Works of Improvement Under Public Law 566. By September 30 signatures from some of the sponsoring organizations and county officials was all that remained before submitting the application for Federal assistance.

Information and Education

A 2-day training session in water resource management was provided Supervisor Office personnel and all Rangers from the Southern Forests in R-9.

Two, one-day training sessions on better logging operation upon National Forest timber sales were provided all Rangers and their staffs from the Chattahoochee National Forest.

State Extension Forester and Home Demonstration office personnel conducted 5 groups totaling 150 individuals around the Laboratory during August 17-23. This was the first attempt in using an Extension Forester to present research results. It offers opportunities of releiving research personnel from conducting lay groups around the Laboratory, but it also calls for a rather complete set of display charts in order that results are accurately presented and proper points emphasized.

Visitors

There was a heavy visitor load this quarter, averaging almost 3 organized groups a week. Thirty groups totaling 243 visitors were shown around the Laboratory.

PIEDMONT RESEARCH CENTER

July - September 1955

Climatic Summary

The weather for this past quarter has been close to normal except for a rainfall deficit in August and September. August rainfall was 2.54 inches below normal and the September rainfall was 2.41 inches below normal. We now have a cumulative deficit for the calendar year of 8.56 inches. The quarterly summary is as follows:

Quarterly Climatic Summary - Calhoun Experimental Forest

	Average temperatures: Max.	Min.	Mean	Highest temp.	Lowest temp.	No. of days with rain	Precip.	Evap.
	°F	°F	°F	°F	°F		Inches	Inches
July	92	68	80	100	55	10	5.25	7.12
August	90	68	79	95	58	8	3.25	5.70
September	85	61	73	96	52	4	1.03	4.31

No new project work was started in Watershed Management work this quarter. Meginnis spent several days at the Piedmont Research Center during September and helped in developing a new lineup of watershed research projects.

Soil Sampling Study

In soil-site work the question always arises as to the number of samples needed to properly characterize the soil conditions on a plot. There is also the question concerning the error to be expected in measuring different properties if a given number of samples are collected. Although the study described below does not fully answer these questions, it does give some valuable information.

One fifth-acre plot was established on each of two hardwood stands, one level and one on a moderate slope growing on Cecil soil. From randomly located pits on each plot, soil samples were collected in each of the A_1, A_2, B_1, and B_2 horizons. Samples were analyzed for moisture equivalent, wilting point, organic matter, and texture.

Statistical analysis of data showed that all horizons were significantly different for properties investigated and that the pits on a plot were not significantly different.

Data given below is for the moderately sloping plot. Table 1 shows mean values and table 2 indicates the number of samples needed on a 1/5-acre plot for the limits of acceptable error listed. Table 3 shows the error to be expected if 8 samples of the surface layer and 4 of each underlying are collected (about the maximum that can be collected on a large scale plot study). The values listed in table 2 could be changed by altering the limits of acceptable error and the values in table 3 could be changed by altering the number of samples collected.

Table 1.--Soil properties of a Cecil soil beneath a hardwood stand (Each value is arithmetic average of 12 samples)

Horizon	Moisture equivalent	Wilting point	Organic matter	Sand	Silt	Clay
	%	%	%	%	%	%
A_1	16.8	7.4	4.4	73	15	12
A_2	13.8	6.5	1.5	70	16	14
B_1	22.5	12.6	1.1	53	17	30
B_2	31.3	20.8	1.1	39	18	43

Table 2.--Number of samples needed to characterize soil properties of a one-fifth acre plot for a given acceptable error.*

Horizon	Moisture equivalent	Wilting point	Organic matter	Sand	Silt	Clay
A_1	7	4	141	17	4	6
A_2	3	4	35	17	1	13
B_1	10	8	23	35	1	29
B_2	5	4	17	27	3	16

*Acceptable error for organic matter ± 0.2%, for all other factors ± 3%.

Table 3.--Errors to be expected on a one-fifth-acre plot with a given number of samples

Horizon	No. of samples	Moisture equivalent	Wilting point	Organic matter	Sand	Silt	Clay
		%	%	%	%	%	%
A_1	8	2.8	2.2	.84	4	2	3
A_2	4	2.6	2.8	.59	6	1	5
B_1	4	4.7	4.3	.48	9	2	8
B_2	4	3.5	3.0	.42	8	3	6

Some conclusions to be drawn from this short study are: (1) the moisture equivalent and wilting point values for a 1/5-acre plot can be readily determined with a few samples; (2) there is more variation in organic matter content than in other properties measured; (3) most variation in the textural analysis comes in the sand separate and is probably due to the laboratory procedure used (hydrometer); (4) the B_1 horizon, a transition between the A and B horizons, is difficult to characterize because of human error. One sample may have more of theA horizon while another may have more of theB. (5) Due to variation between soil series, topographic positions, etc., it is not possible to arrive at an exact number of samples needed for this large scale plot study. The data does give a good idea as to variation to be encountered and the relative accuracy of laboratory procedures.

SEMI-ANNUAL REPORT
Forest Influences Research
Southern Forest Experiment Station

April 1955 - September 1955

Vicksburg Infiltration Project

The field work of the soil strength-moisture surveys was completed and the survey leaders returned to Vicksburg in June. The survey data was processed and a first round of soil-moisture predictions completed for each site by September. The attention of the staff is now focused upon report preparation to cover the activities and results of the Project accomplished during the past two years.

The only field work in progress at present outside of Vicksburg is the Puerto Rico extension started in July in cooperation with the Tropical Forest Research Center. Robert A. Tobiaski and Edmond I. Swensen (who worked with the Lake States Survey) have initiated the work there, establishing 8 sites for daily soil-moisture measurements with fiberglas units, and 22 reconnaissance sites where periodic soil-moisture samples are to be taken to check the prediction relations developed from the daily record at the unit sites. Broadfoot journeyed to Puerto Rico shortly after the extension was started and helped to select the sites and to make arrangements with the cooperators. Seven of the stacks of units are within a 20-mile radius of Rio Piedras. One was established in cooperation with the Puerto Rico A. & M. College at Mayaguez (100 miles from Rio Piedras).

Collection of data is continuing from the soil-moisture study of cultivated vs. non-cultivated areas established at Vicksburg last spring. No attempt has been made to analyze the data so far collected but it appears from preliminary scanning that the soil drys at about the same rate in the 0 to 6-inch layer regardless of cultivation treatment, even for plots bared of vegetation. In the 6 to 12-inch and 12 to 18-inch layers, soil drying appears to be related more to the density and vigor of the vegetation than to the frequency of cultivations. The plots plowed once in early spring had a better herbaceous cover than those cultivated monthly or not at all.

After the return of the Survey leaders, much of the effort at Vicksburg went into making a preliminary prediction for each of the 630 sites. In general, the results of predictions were good. The average differences of the predicted from the actual soil moisture values for all sites are given in the following table. Some of the variation was due to the effect of ground water. If those sites affected by groundwater are removed, the average differences are usually less.

		All sites		Groundwater sites removed	
	Depth inches	No. 1/	Av. Diff. inches	No. 1/	Av. Diff. inches
Southern	0-6	178	0.34	141	0.30
	6-12	178	.29	141	.27
Lake States	0-6	100	.29	74	.31
	6-12	100	.32	74	.29
Intermountain	0-6	138	.36	106	.26
	6-12	138	.31	106	.23
Northeastern	0-6	135	.54	112	.45
	6-12	135	.49	112	.39

1/ Some sites are not included because June rainfall figures for several states have not yet been furnished by the Weather Bureau.

A statistical study is being initiated to determine the factors which influence the prediction relations between sites, and to derive better average prediction relations between sites, and to derive better average prediction relations. It is hoped that the survey deviations can be even further reduced by the refinement of relations in the correlation study. The Project has not been able to locate a statistician to assist in these studies but arrangements have been made with the Purdue University Statistical Laboratory to give us consulting service.

At present, the major effort is the preparation of a summary report for the Army Engineers covering prediction relations developed from all sites with detailed (usually daily) soil-moisture records. This summary will include the data collected by the Extensions, the data furnished by cooperators, and also (in condensed form) the relations already published in Project Progress Report No. 3, issued in October, 1954, by the U. S. Army Engineers.

Publications

"Soil Moisture Regime in Some Forest and Non-Forest Sites in Northern Wisconsin" by John L. Thames, Joseph H. Stoeckeler, and Robert Tobiaski. Soil Science Society of America Proceedings 19(3): 381-384. July 1955.

"The Development of Methods for Predicting Soil Moisture Content, Report on the Fairbanks, Alaska Extension," written by Robert Tobiaski and David E. Larson was published by the Waterways Experiment Station as Miscellaneous Paper 4-135, July 1955.

"Field Tests of Nuclear Instruments for the Measurement of Soil Moisture and Density," written by E. S. Rush (WES) and K. G. Reinhart was published by the Waterways Experiment Station as Miscellaneous Paper 3-117, March 1955.

Manuscripts being edited

Lull, H. W., and Reinhart, K. G. "Soil-Moisture Measurement." To be published very soon as an Occasional Paper of the Southern Forest Experiment Station.

Horton, J. S. "Use of Fiberglas Units in Mountain Soils" will be published in the Proceedings of the Western Snow Conference.

Carlson, Reinhart, and Horton, "Predicting Soil Moisture in the Surface Foot of Soil" will be published by Soil Science Society of America Proceedings.

Manuscripts in preparation

"Soil-Moisture Constants," by W. M. Broadfoot. The first draft has been written but not reviewed by the Vicksburg staff.

"Estimation of Field-Maximum Moisture Content," by C. A. Carlson. In process of preparing first draft.

Program Expansion

Increased funds for FY 1956 made possible an expansion of the modest Tallahatchie watershed management research program. Two forester-hydrologists, Stanley J. Ursic and Dr. James L. Smith, have been added to the staff. A project analysis is now being prepared.

New watershed management research will be directed primarily at basic information needs vital to more efficient planning, installation, and evaluation of the flood and erosion control program of the Yazoo-Little Tallahatchie Flood Prevention Project. This is one of the largest flood and erosion control land rehabilitation projects in the Nation, and is jointly conducted by the USDA Forest Service and Soil Conservation Service in the Yazoo basin of north Mississippi. Results will also benefit all watershed rehabilitation projects throughout the mid-South.

The general types of information most needed by the project and tentatively proposed for research investigation can be summarized as follows:

1. For design and planning of engineering structures and improvement works: runoff and erosion rates on woodland and potential woodland areas of various soil-slope-cover complexes; sediment deposition rates and patterns below problem areas of different types; runoff and erosion deceleration following remedial treatment of impaired lands.

2. For increased effectiveness of remedial land treatments; a practical system of site classification to guide treatment of critically eroded areas; most effective and economical type and degree of site improvement practices needed to successfully revegetate various types of adverse sites; improvement of erosion control land treatment techniques and practices.

3. For evaluating program effectiveness: comparative effectiveness of various vegetative and mechanical treatments in reducing runoff and in stabilizing and rehabilitating soils; effectiveness and benefits of overall composite remedial program on a watershed basis for watersheds of different sizes; methods of assessing sediment and flood damage to land, crops, channels, and man-made structures.

4. For supplementary information: additional basic studies.

Specific details and scheduling of the proposed program will be outlined in the project analysis.

Current studies

Details of current soil-site studies have been previously described. All are relatively new installations which to date have produced no results. Following is a progress report on established studies and descriptions of two proposed for early installation.

Grasses and Legumes for Erosion Control: A study to determine the effects of selected grasses and legumes on soil hydrologic properties was established in north Mississippi in January 1955. During January and February, several frontal storms occurred which raised the soil moisture content appreciably and made conditions favorable for seed germination. Then during the week of March 14, two storms of 1.25 inches occurred two days apart. Two days later, approximately 6.5 inches of rain fell in an eight-hour period, an intensity which probably represents a 100-year storm. This rain did considerable damage to the grass plantings by transporting seeds and washing away newly germinated seedlings. Fall measurements will determine the extent of damage and need for reinforcement plantings.

Pine Response to Fertilizer: A study to determine the effects of single and repeated fertilizer applications on survival and growth of loblolly pine seedlings planted on severely sheet eroded sites was reestablished in April 1955. Bermuda grass (Cynodon dactylon) caused considerable trouble on the blocks located on loessial soil. Control was attempted by spraying maleic hydrazide in heavy concentration on the grass and clipping the grass two weeks later. Apparently the favorable moisture conditions overcame the inhibitor, for the grass continued to grow vigorously. Pine seedling survival at present is approximately 90 percent. In the spring of 1956, a randomly selected half of each plot will again receive the same treatment as was originally applied.

Pine Response to Legumes: A study was reinstalled in north Mississippi in March 1955 to determine the response of loblolly pine seedlings planted on adverse sites to interplanted legumes. Cursory

examination of the plots indicates that pine survival is good (85 - 90 percent). Of the legumes planted, only bicolor caught well. Lespedeza sericea shows only a fair catch and Trifolium incarnatum failed to catch. Accordingly, some reinforcement planting of the legumes, except for bicolor, will be done next spring.

Soil Moisture and Tree Growth: A cooperative study was installed in north Mississippi in April 1954 to determine the relationships between tree growth and soil moisture content as it varies from day to day and season to season; also to obtain soil and soil moisture data for the Vicksburg Infiltration Project. The study areas have completed their second growing season, which was the proposed length of the study. Sufficient data are in hand to develop accretion and depletion curves for the soil profiles. During the fall, the data will be analyzed to find relations between soil moisture content and tree radial growth.

Site Changes with Species Conversion: A study was installed in north Mississippi in March 1954 to determine the nature, rate, and extent of site changes--especially those affecting infiltration and retention of water--associated with conversion of ridge stands of worthless hardwoods to pine. Despite the severe drouth of 1954, survival was excellent. Growth during this wet year has been highly satisfactory. A light release was imposed on the blocks this spring to relieve the seedlings of sprout competition. In view of the seedlings' vigorous growth, probably no additional release work will be needed. Changes in soil properties of the first six inches will be measured periodically over the next 20 years.

Soil Moisture Variations with Ridge Conversion: This study is designed to determine the variations in soil moisture content on blackjack-post oak ridges when the ridges are converted to pine with different intensities of hardwood control. A study plan has been prepared and submitted for approval. Three blocks will be established on blackjack-post oak ridges and planted 6 x 6 with loblolly pine. Treatments will consist of three degrees of hardwood removal: large overstory, small overstory and understory, and a combination of the two. Soil moisture will be measured during the growing season and will be related to seedling survival and growth.

SEMIANNUAL REPORT
WATERSHED MANAGEMENT RESEARCH
TROPICAL FOREST RESEARCH CENTER

April - September 1955

General

This issue of the Semiannual Report introduces, perhaps prematurely, the youngest member of the Division of Watershed Management Research. We ourselves certainly are not premature. The need for such a program in this work province has long been evident and plans have been in the mill for several years to investigate the problem.

Huckenpahler transferred from the Southern Station to the Tropical Center in the middle of March primarily to handle the training of foreign nationals sent to Puerto Rico for that purpose. His incidental duties are concerned with watershed problems in Puerto Rico and the Virgin Islands. Since his arrival he has been full time on training and little has been done along the influences line. Prospects for future training activities indicate that he will be kept pretty busy with his primary duties.

Presumably as a result of a consultants' conference held last December in Vicksburg to review soil-moisture prediction work (we have read the last report), R. A. Tobiaski and Ed Swensen reported early in July to begin work on the Tropical Extension, Vicksburg Infiltration Project. Toby recently spent five months on similar work in Alaska (he's a man of extremes, it seems); Ed came to us from the infiltration project at Rhinelander, Wisconsin. The boys were lucky; they arrived just in time for the 50th anniversary picnic which featured the island's traditional "lechón asado."

Tropical Extension, Vicksburg Infiltration Project

Puerto Rico was chosen as the site for a study of soil moisture-strength relationship of tropical soils because of its wide variety of soils and rainfall, and the administrative, laboratory, and library facilities available at the Tropical Forest Research Center.

The purpose of the study is to develop soil moisture prediction methods and soil moisture-soil strength relationships for representative soils under tropical rainfall conditions. The project is scheduled to be completed in one year.

Eight sites for daily moisture readings were chosen; fibre glass units have been installed and daily records will begin immediately. Twenty-two survey sites for extensive soil moisture-strength sampling tests have been located. Sites were picked to include primarily clay loams and clays.

Broadfoot spent a week here in July approving site locations and disapproving our mountain roads. He's been away from West Virginia too long!

Bird's Eye View of Puerto Rico

Watershed problems in this work province are extremely important; they are also different from anything encountered in the States and vary considerably within the area.

(Over)

In the Virgin Islands, there are no live streams nor is there an adequate ground water supply. Most of the water used is rain water collected on catchment surfaces and stored in cisterns. At the present time, the U. S. Navy is transporting water to the island of St. Thomas.

Puerto Rico with its range in annual rainfall of from 30 inches in the dry southwest to over 200 inches in the Luquillo mountains, has its own peculiar water problems. Conditions vary from critical shortages in the southern part of the island and seasonal shortages most everywhere to excessive unused runoff in some mountain valleys. Its 2,211,000 people concentrated on 2,198,000 acres (at this density the U. S. would have a population of nearly 2 billion) require and use much water to supply agricultural, domestic, and industrial needs.

Land Use and Conditions. Puerto Rico is primarily an agricultural island. Notwithstanding the fact that over 800,000 acres or 37 percent of the land surface exceeds 45 percent slope, over 1,800,000 acres (nearly 85 percent) is classed as farmland. About one half the cropland or approximately 400,000 acres are planted to sugarcane. A study in 1951 showed that over half of the cane was on slopes over 16%; 11 percent was on slopes over 36%. Nearly a quarter million acres are in clean cultivated crops such as bananas, tobacco, sweet potatoes, corn, etc.

The island was originally completely forested. There are now only about 119,000 acres of timber forests, 80 percent of which has at one time or another been in cultivation (some of it periodically). In addition, there are about 140,000 acres in forest covered coffee plantations where leguminous trees, mostly nontimber species, are used for shade. Six Hundred thousand acres because of excessive slope, poor soil, or very heavy rainfall are classed as forest land because they cannot be cultivated continuously without soil deterioration. More than one half of this area has no tree cover.

Nearly one half (forty-eight percent) of the island has suffered severe erosion (75% or more of the topsoil lost). Twenty-two percent of the land is slightly to moderately eroded (25 to 75 percent of the topsoil lost); only 15 percent is classed as uneroded.

Land use and related problems are complicated by the fact that there are 115 soil series with 352 different types and phases of soil present on the island.

Watershed Problems. The factors of intense cultivation, severe erosion, steep slopes, and soil variety all lead to pressing watershed management problems. The increasing development of reservoirs to impound water for irrigation, hydroelectric power, and domestic uses throughout the island makes it imperative that these problems be investigated.

There are at present about 100,000 acres of land under irrigation principally by gravity systems dependent upon eight reservoirs. Plans are under way to put an equal area into production by irrigation.

At the present time there are 17 hydroelectric power plants with a total capacity of 96,575 k.v.a. The increasing demand for electric power indicates that the potential production of hydroelectric power will be met by 1975. Irrigation, power, and industrial water needs require continuous delivery. The seasonal distribution of rainfall in Puerto Rico necessitates ample capacity to store runoff during wet seasons for use during the dry periods. The efficiency and life expectancy of a reservoir therefore is based primarily on the amount of sedimentation brought about by conditions within its watershed.

Sedimentation and the resultant loss of storage capacity of reservoirs in Puerto Rico is serious. Sedimentation in three of the older reservoirs, each 37 years old in 1950, show the seriousness of this problem.

Reservoir	Orig. storage cap.	Area of watershed	Condition in 1950: Estimated Sedimentation: Volume	Condition in 1950: Estimated Sedimentation: Percentage	Average annual loss in capacity
	Acre-Ft.	Sq.Mi.	Acre-Ft.	Percent	Percent
A	9,544	43.4	4,750	49.7	1.34
B	4,918	133.0	4,318	95.9	2.59
C	2,687	58.0	1,887	70.2	1.89

Reservoir "A" is so important to the irrigation of 51,000 acres of sugarcane below (33,000 by gravity and 18,000 by wells and pumps) that the height of the dam was increased 16 feet at a cost of $2,000,000 in 1950.

Flood damage resulting from heavy rains accompanying hurricanes that pass near the island (averaging two per year from 1915 to 1945) is principally to stream channels through bank erosion, and to irrigation systems by filling ditches with debris and silt. Damage to crops is, however, serious. Data collected by the U. S. Army Engineers in an area involving six watersheds totaling 154,000 acres show that 20,140 acres, or 13 percent (including 15,720 acres of sugarcane and 430 acres of urban property) is subject to occasional flood damage. If the same percentage of all watersheds is subject to flooding, the total area damaged by floods is approximately 280,000 acres.

Summarizing

We are starting slowly; watershed conditions are variable and some are unique; and the problems show promise of being complex and provoking.